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QUANTITATIVE GENETIC STUDIES IN SELECTED LINES OF TETRAPLOID AND HEXAPLOID ALFALFA

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled 'Quantitative Genetic Studies in Selected Lines of Tetraploid and Hexaploid Alfalfa' submitted by Shio Murti Singh in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

ABSTRACT

Two sets of diallel crosses involving seven tetraploid and five hexaploid selected alfalfa lines were studied for various quantitative characters in the field trials during the two growing seasons of 1968 and 1969. The characters seed yield, forage yield, and dry matter per plant were used as the basis for further selection, against the tetraploid check variety Grimm.

The cross pollination check using male sterile line 20 DRC was found to be 1.22% and self fertility of the hexaploid and tertraploid lines ranged from 30% to 40%.

In general, all the tetraploid crosses were better than the check variety for all the main characters, viz., seed yield, forage yield and dry matter per plant. Though the seed yield of the hexploid crosses was better than that of Grimm, they were poor in vegetative production. Most of the crosses exhibited a high degree of hybrid vigor.

Although the variances due to general (GCA) and specific (SCA) combining ability were significant for most of the characters in both populations, the values of SCA were higher in tetraploids than those for GCA. Higher values of SCA may be expected from selected lines. Also the estimates of narrow sense heritability were found to be very small as compared to the broad sense value in tetraploids, suggesting that the variation due to additive gene effects is quite small; most of the variation can be attributed to various

allelic and nonallelic interactions. In hexaploids, a balance of additive (fixable) and nonadditive (nonfixable) gene action may be considered to account for the expression of various characters on the basis of the above studies.

For most of the characters studied there were no differences in reciprocal crosses.

The forage yield showed positive association with growth in spring, growth in fall, growth in year of establishment, frost resistance and plant vigor, as was evident from simple, genotypic and phenotypic correlations. Similar correlations were also noted between seed yield and seeds per pod, dry matter content and frost resistance. The effect on total forage yield seems to follow a path through growths in spring and fall which are contributed by leaf size, plant vigor, frost resistance and dry matter per plant which in itself is affected by plant vigor and plant height. The partial correlations followed the trend of simple correlations discussed above.

Selection indices comprising the direct components of seed yield did not show any appreciable improvement over the straight selection. The forage yield could be improved by using several selection criteria.

Use of heritability in the broad and narrow sense, selection indices and prediction of progress may be possible and profitable in cases where the characters are expressed by individuals which constitute definable populations.

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INTRODUCTION

The search for superior germ plasm and investigations on methods for its utilization in forage crop improvement have been intensified in the last decade. The value of alfalfa lines as parents of commercial varieties is determined primarily by their combining ability and the knowledge of the type of gene action for yield and other quantitatively inherited characters. The increased vegetative yield from hexaploid alfalfa prompted various workers to breed hexaploid varieties. Although the seed setting of hexaploids was disappointing, selection for it seems to be effective (Lesins, Singh and Baysal, 1969).

In the present study, the selected lines of tetraploids and hexaploids were tested for the relative magnitude of additive, dominance and epistatic genetic effects and selections were made of the hybrids superior in seed and forage yielding ability. The diallel cross approach was used in this study, since it: 1. provides a systematic approach to large scale studies of continuous variation, 2. provides reliable genetic information and 3. assures genetically sound elimination of a high proportion of arrays and crosses of low selection potential. Information obtained from diallel cross analysis has been used in two ways:

1. to characterize crossing relationships among the

parental lines or varieties with the goal of identifying crosses expected to be good source material for selection, and 2. to obtain genetic information regarding the parental material (Griffing 1956b, Hayman 1960). This knowledge of genetic effects would help in the choice of the most suitable breeding procedure. The gene effects vary with the environmental situation, so any sort of gene effect has a meaning only for the set of environmental conditions under which the effect was measured.

The objectives of this study are:

(a) to ascertain the relative importance of general and specific combining ability and that of reciprocal effects for various quantitative characters at tetraploid and hexaploid levels.

(b) to study the relative importance of the type of gene action at the ploidy levels considered.

(c) to evaluate the extent of heterosis for the main characters studied.

(d) to determine the relationships between the quantitative characters studied at two ploidy levels.

(e) to select the best lines and best single cross combinations for seed and forage yielding ability.

II. REVIEW OF LITERATURE

Interest in Alfalfa (*Medicago sativa* L.) breeding has increased greatly and considerable emphasis has been placed on breeding alfalfa for improved seed and forage yield, along with other characters. The literature related to the present study may be conveniently grouped into three categories as follows:

1. Genetic Studies

(a) Combining ability

The definition of combining ability,as usually used, was given by Sprague and Tatum (1942) and refers to the relative performance of a line in hybrid combinations. This relative performance has been sub-divided into two categories: general and specific combining ability. General combining ability is the average performance of a line in a number of hybrid combinations. Specific combining ability is used to designate those cases in which certain combinations do better or worse than would be expected on the basis of average performance of the lines involved. The general combining ability variance has been related largely to additive gene action and the variance for specific combining ability ascribed to dominance and epistatic deviations as well as to genotypic x environmental interactions.

Levings and Dudley (1963), gave the coefficients of genetic variances of general and specific combining ability

for tetraploids. According to them, variance due to general combining ability consists of 1/4 σ^2 additive (A), 1/36 σ^2 digenic (D), 1/16 σ^2 due to A X A, 1/44 σ^2 due to A X D, and 1/1296 σ^2 due to D X D; whereas variance due to specific combining ability is attributed to 1/6 σ^2D, 1/12 σ^2 trigenic (T), 1/36 σ^2 quadrigenic (F), 1/8 σ^2 A X A, 7/72 σ^2 A X D and 31/648 σ^2 D X D. Thus in contrast to the diploids, digenic variance analogous to dominance variance at the diploid level occurs in the components of both general and specific combining ability.

The problem of producing all possible single crosses among a number of parents probably accounts for the paucity of literature dealing with precise estimates of general and specific combining ability for quantitative characters in alfalfa and many other forage species. Combining ability studies have been reviewed by Hayes et al. (1955) for corn and other crops; by Hanson and Carnahan (1956) for forage grasses; and by Kehr and Graumann (1958) and Gardener (1963) for alfalfa. Bolton (1948) evaluated the combining ability of thirteen non-inbred alfalfa clones, and thirteen first or second generation inbred clones by using incomplete diallel crosses within each group. During this study he recognized the importance of both specific and general combining ability in evaluating alfalfa for forage and seed yield. He also noted the great variation in combining ability

for seed yield both among inbreds and clones.

Tysdal et al. (1942) suggested the use of poly-cross method to measure the general combining ability, the limitations of which were pointed out by Davis (1955). He studied dry-weight, height, crown width, seedling height and vigor rating in alfalfa progenies. Tysdal and Crandall (1948) tested the general combining ability of their alfalfa clones for forage yield, bacterial wilt resistance and obtained a similar ranking of combining ability of their six clones, whether poly-cross, single cross or top-cross methods were used.

Carnahan et al. (1960) analyzed a diallel set of 91 crosses in fourteen alfalfa clones for seedling vigor and fall growth habit. Estimated variance components for general (by far the largest component) and specific combining ability and the interaction of these with locations were all highly significant for both characters. Kehr (1961) working with six alfalfa clones found the general combining ability component larger for the fall growth habit and rate of recovery after cutting. The specific combining ability component was larger for forage yield and spring growth habit. The six clones were previously selected for forage yield and spring growth habit on the basis of their general combining ability. Frakes et al. (1961) made a diallel cross analysis of four clones, two prostrate and two upright genotypes of alfalfa. They

found high general combining ability for plant height and largest stem and low general combining ability for natural width and number of stems. Wilcox and Wilsie (1964) reported highly significant general combining ability effects for fall growth habit, forage yield and spring vigor. Significant specific combining ability was also noted for the above characters. The components of variance for general effects were greater than those of specific effects for these characters.

Dudley (1963) noted significant specific combining ability effects for spring growth, recovery, plant width and plant height, but not for leaf hopper yellowing. The general combining ability component was biased upward by an amount varying from 40% for leaf hopper yellowing to 218% for spring growth when estimates from Griffing (1956a) model (method I, which includes reciprocals) were made and compared to the selfing model. He concluded that to obtain meaningful estimates of genetic variance components from alfalfa crosses, crossing procedure insuring 100% cross fertilization must be used. Davis and Gartner (1966) found no influence of self incompatibility on general combining ability effects with or without emasculation. Dudley et al. (1969) obtained significant estimates of total genetic variance, general combining ability and covariance of parent-offspring for yield, recovery after first and second cuts, spring growth and

fall growth. Estimates of specific combining ability were not significant for any of these characters. They also concluded that either trigenic or epistatic genetic variance was important for forage yield, recovery after first and second cut, and spring growth. Both additive and non-additive genetic variances were found to be important in their material.

(b) Reciprocal Effects

Bolton (1948) reported that progeny of reciprocal crosses, with very few exceptions, showed no differences between reciprocals for seed and forage yields of alfalfa. Liang (1961) could not find reciprocal difference in forage yield between ten single crosses of alfalfa clones. He noted some differences in the components of forage yield and pointed out that this could be expected because of the heterozygosity of the clones. Davis and Panton (1962) found no reciprocal difference between six hand-pollinated alfalfa clonal crosses (obtained with emasculation) for yield, vigor, height, crown width and seedling height. Liu (1964) also found no differences in clonal crosses for forage yield, plant height, stem number and leaf weight. Hanson et al. (1964) observed reciprocal differences in two clonal alfalfa crosses, obtained without emasculation but attributed the differences to selfed seeds. Frakes et al. (1961) reported reciprocal differences in six alfalfa crosses, made with

emasculation, for dry weight. Wilcox and Wilsie (1964) showed that reciprocals of certain alfalfa crosses grown as spaced plants in the field differed in total yield and in fall growth habit. They concluded that reciprocal differences may be of minor importance as far as general and specific combining ability are concerned. Carnahan (1963) in studying 95 alfalfa clone crosses and their reciprocals representing sixteen cytoplasmic sources, noted only few instances of significant reciprocal differences in height at four and eight weeks of age. No significant difference for dry weight at twelve weeks of age was found. Seed weight of certain reciprocals differed by more than 30%. Reciprocals of one cross and of one cytoplasmic source including eight crosses were significantly different in unifoliate leaf area. In each case, the member of the reciprocal pair with taller seedlings had numerically heavier seeds and greater unifoliate leaf area. These reciprocal differences were largely attributable to the relation between seed size and photosynthetic area in seedlings. Wilcox and Wilsie (1964) attributed reciprocal differences for forage yield to interaction between cytoplasm and genotype. Davis and Gartner (1966) studied 28 F_1 families and their reciprocals made with and without emasculation. Significant reciprocal differences in both emasculated and unemasculated crosses were found for seedling height, seedling weight, recovery, plant height,

plant width and plant weight which were attributed to maternal effects. Significant maternal effects for seeds per flower and percentage of flowers setting pods were reported by Rice (1968) in his diallel crossing program involving eleven clones of Buffalo alfalfa. Pedersen (1968) also reported reciprocal differences for seed and hay yield in a cross between two alfalfa clones as affected by method of pollination.

2. Association Between Characters

A knowledge of interrelationships among characters that affect forage and seed yield is necessary if selection for simultaneous improvement of forage and seed yield is to be effective. Although many workers have been actively engaged in alfalfa breeding, very little work on the interrelation of various plant characters can be found in the literature.

Burton (1937) reported a highly significant positive linear or near linear correlation between forage yield and plant height, and that the high yielding plants usually had a large number of stems. Stem length of six week alfalfa seedling could be used for early elimination of plants inferior for yield. Tysdal and Kiesselbach (1944) found high yielding plants to be taller, more upright and more sparsely leaved. They had thicker and more woody stems, though these characters do not show complete linkage. A highly significant correlation value of 0.288 between self and cross fertility was

observed by Burton (1948). Battle and Pettem (1953) showed that alfalfa plants selected for high seedling vigor showed consistent superiority for survival after transplanting, yield and rapidity of spring growth. Dudley and Hanson (1961) studied the correlation between several characters in F_2 population. Highly significant positive correlations were noted between height, spring growth and recovery, between plant width and yield, between leaf width and leaf length, and between crown width and procumbance. They also reported that the genotypic correlations in general were similar to the phenotypic correlations both in sign and magnitude.

Carnahan et al. (1960) obtained a very high correlation between seedling vigor at Indiana and Nebraska and seedling vigor and percent seedling stand in Pennsylvania. Highly significant correlations between yield and vigor, natural height, crown width, seedling height (four weeks) were noted by Davis and Panton (1962). Larson and Smith (1963) presented convincing evidence of high association between winter hardiness and average height, percentages of extra tall and short plants and growth habit of plants. Crown weight was found to be correlated with the percentage of winter injury. In their investigation of interrelation of various characters in alfalfa, Nielson and Mortensen (1963) showed that plant height was closely and positively correlated with vigor. Similarly, seed yield and seed

set and date of flowering termination, date of ripening and hay yield at the time of seed harvest were also found to be correlated.

Busbice and Wilsie (1965) observed a positive correlation between fall growth, spring recovery and yield. They concluded that the recombination of genes for fall growth, winter hardiness and rapid recovery after cutting had occurred and that simultaneous selection for these characters in the material would be effective. Daday (1968), working with crepping rooted alfalfa showed highly significant positive correlations between creeping rootedness, plant diameter and persistency among families under continuous grazing.

Three indexes of self and cross compatibility, i.e., percentage of flowers producing pods, seeds per pod and seeds per flower, were found to be associated by Gray et al. (1969).

The Path coefficient analysis by Frakes et al. (1961) showed natural plant width affects directly in its effect on the yield whereas stem number affects it indirectly. A large proportion of the significant association of height and long stem length on yield was indirect in its effect via width. Liang and Riedl (1964) observed simple correlations between forage yield and plant height, number of leaves, number of internodes

and number of stems. Plant height, seed size, fertility and number of stems were positively associated with seed yield. However, the Path coefficient analysis showed a somewhat different picture. It indicated that plant height and number of stems had the greatest influence on forage yield. For seed yield, seed size exerted a negative influence rather than positive. Plant height and fertility seemed to be the most important factors affecting seed yield.

3. Fertility and Pollination

It is evident that in areas of origin of primitive alfalfa, cross fertilization by wild bees may be considered as prevalent, though self fertilization may occur to some extent. The question of fertilization has become more complicated as it spread to new areas, especially where there is not an abundance of pollinating bees.

Brink and Cooper (1936), Carlsson (1935) are among few of the early workers to report that pod and seed setting may take place to some extent in non-tripped flowers. As early as 1927, Kirk pointed to the decided reduction in seed yield resulting from self fertilization but also suggested the possibility of breeding for high seed yield by selection. Tysdal and Clark (1934) obtained

increased response to selection for seed yield on a general selfing program. Temperature and light were found to have an important bearing on seed production.

Lesins (1950) stated that tripping of flowers seems to be necessary for the seed setting, though plants could be found which set seed without tripping. Tripping in cases of cross pollination is accomplished by pollinating bees; but in self pollination, in the absence of bees, automatic tripping seems to be very important. Automatic tripping has been reported to be quite variable depending on the material and growing conditions. As little as 2.8% of auto-tripping was noted by Tysdal (1940), whereas Knowles (1943) observed it to be as high as 81% in one selection.

Lesins (1950) noted a range of 19.5% to 64.9% of automatic tripping in his material. Kirk (1933) proposed use of autogamous, i.e., auto-tripping and self fertile plants for building up strains of superior seed yield.

Self fertility is another important factor if self fertilization has to be utilized. This seems to be quite variable in different populations and growing conditions. Tysdal and Kiesselbach (1944) presented a detailed study on self fertility. Lesins (1957, 1961) mentioned it as an inherent and unchangeable quality. He also observed about 1/4 plants as poor and more than

1/2 of the entire population as medium self-fertile. Genetically, self fertility seems to be recessive, as pointed out by Wilsie and Skory (1948), Armstrong (1952) and Whitehead and Davis (1954).

The nature of the genetic linkage between self tripping and self fertility is not known. Wexelsen (1946) found little linkage for the two characters in non-inbred populations. The two characters seem to be repulsive under conditions where cross pollination is taking place (as it will lead to selfs, which are low in vigor) but under conditions where inbreds have to compete among themselves, genotypes with less decline in self fertility may be expected, i.e., plants with high self tripping and good self fertility would be favored.

Lesins (1950, 1961) reviewed the problem of cross pollination. Early workers evaluated outcrossing in alfalfa as high as 85% on the basis of recessive marker traits [Burkart (1937), Knowles (1943), Bolton (1948), and Tysdal et al. (1942, 1948)] which was surprising especially when few pollinating bees were present. Lesins (1961) took approximately 2.1% of the set on male sterile line 20-DRC as a measure of outcrossing in the Edmonton region. He (1950) also noted negligible pod and seed set without tripping. About 0.8% of flowers visited by honey bees were noted to be tripped. At this stage it can be concluded that alfalfa by

natural origin is an insect cross pollinating crop; but with adaptation to new areas where bees are scarce, plants favoring self fertilization could be selected. There are two processes involved in self fertilization: automatic tripping and self fertility. They vary from material to material and also under various growing conditions. Kirk (1933) and Tysdal and Clark (1934) have also indicated that inbred lines may be selected which do not reveal a drop in productivity after several generations of inbreeding. The variety Ferax, as a result of selection for high seed set, could be mentioned.

Lesins (1950) observed some selected plants good in seed setting and medium-to-good in vegetative growth in variety Ferax, and noted almost no cross pollinating insects in the nursery. It seems probable that in the field, self pollination takes place in the absence of pollinating insects.

III. MATERIALS AND METHODS

1. Materials

The material consists of tetraploid and hexaploid Alfalfa (*Medicago sativa* L.), maintained in the Department of Genetics, University of Alberta.

Forty-one lines of tetraploid and seventy-one of hexaploid were seeded in a randomized block design with tetraploid variety Grimm as the check. After two years of seed and forage yield tests, seven tetraploid lines superior in seed yield and good in forage production were selected for further work. They were numbered 5, 16, 34, 63, 67, 201 and 242. Similarly, four of seventy-one hexaploid lines were selected on the basis of their superiority in yield trials and numbered 1, 2, 3 and 4.

The seven tetraploid lines were used in a diallel crossing programme, which also included reciprocals and selfs. Another partial diallel crossing system included the four selected hexaploid lines and a newly produced (4n x 8n) line, number 5.

The selected plants of the tetraploid and hexaploid lines were transplanted from the field to the greenhouse in September, 1967. They were kept at about 70°F. with artificial daylight of about 15 hours and a relative humidity of approximately 45%, these conditions having been found satisfactory for profuse flowering and good

growth.

Crosses were made in all possible combinations, including reciprocals in tetraploids but excluding reciprocals in hexaploids, by emasculating newly opened buds. For emasculation, the base of the standard petal was cut with fine scissors. The staminal column was released by pressing the base gently with fine forceps. The inflorescence was then dipped in 57 percent alcohol for a few seconds and immediately rinsed in distilled water. The anthers were then sucked off by a fine nozzle attached to a vacuum pump. Pollen from the desired male parent was collected on a toothpick and applied to the stigma. The inflorescence was tagged with required details.

The mature pods were harvested by hand and the percentage of pod set and the number of seeds per pod set were noted.

About one hundred seeds of each crossed and selfed progeny were gently scratched on sand paper to break their seedcoat and then sterilized by alcohol treatment. These were started on moist filter paper in petri dishes kept in a controlled temperature of 8^{o}C. during the second week of April,1968.

After the emergence of the radicle, seedlings were planted in wooden flats (19.5" x 11.5"), filled with the soil mixture (3 soil: 2 peatmoss: 1 sand: 1 perlite).

They were allowed to grow in the greenhouse for about one month and then were transferred outside to coldframes for about one week, for acclimatization to field conditions.

In the last week of May they were transplanted to the field using a randomized block design with eight replications.

The forty-two crossed and seven selfed tetraploid genotypes, with Grimm as a check and a male sterile line 20 DRC (to check the percentage of cross pollination) were included in one test and the ten crossed and five selfed hexaploid lines with Grimm as check were used in another test. The two tests were conducted in the same field at the University Parkland Farm, so cross pollination data on male sterile lines included in the tetraploid test, was used for calculating the amount of cross pollination in the hexaploids. No extra honey bees were provided to facilitate pollination.

The hexaploids were started about a month later, using the same technique described for the tetraploids, and were transplanted to the field on June 3 and 4, 1968.

In the field plan, plants were grown ten in a row, 90 cm. apart, the distance between rows being 90 cm. Two border rows 90 cm. apart were seeded with variety Grimm bordering the whole experimental area.

The field was kept free from weeds during all growing seasons.

The following characters were studied:

(T1) First cutting (kg.)

(T2) Second cutting (kg.)

(T3) Total forage yield (kg.)

(T4) Seed yield (gms.)

(T5) Number of seeds per pod

(T6) Dry-matter per plant (kg.)

(T7) Vegetative yield in the year of establishment (kg.)

(T8) Leaf area (cms.)

(T9) Leaf length (cms.)

(T10) Frost resistance

(T11) Vigor of plant

(T12) Growth habit

(T13) Plant height (cms.)

(T14) Percentage of pod set during crossing

(T15) Number of seeds per pod set

The characters T1, T2, T3, T4, T5, T6, T13, T14 and T15 were also recorded on hexaploids and designated as X1, X2, X3, X4, X5, X6, X7, X8 and X9, respectively.

2. Methods of Collecting Data

All the characters mentioned above were recorded for each plant. The spring growth was measured at the time of the first cutting, taken in the first week of July, and weighed as the fresh weight per plant. The hexaploids

were harvested in the third week of July. Similarly, fall growth was recorded when the second cutting was taken, after seven weeks of growth. The total forage yield represents the total of the two cuttings taken during the season, recorded on four replications.

The other four replications were left for the seed yield test. The seed yield represents the seeds obtained from each plant. The dry-matter per plant was noted as the weight of dried chaff. The number of seeds per pod was recorded on approximately one hundred pods collected from each plant before harvesting. Mature plant height was noted on the plants left for seed set.

The vegetative yield in the year of establishment was recorded as the total forage growth in 1968, which was recorded as the fresh weight of the plants. It was taken on all eight replications. The leaf length and leaf area represents the length and area of the central leaflet of well developed leaves. Five measurements were made on each plant and the mean recorded. Leaf area was calculated by multiplying the length by the width.

Frost resistance, vigor and growth habit were recorded by assigning proper grades to each plant. Plants not affected by frost were graded 9 (resistant) and those highly susceptible were graded 5, recorded

after the heavy frost on June 12 and 13, 1969. Similarly, before the frost, well grown and vigorous plants were graded 9 and poor ones 4, the rest ranging in between. Growth habit was noted on well developed plants. The completely erect plants were graded 9 and the completely prostrate ones 4; others were graded accordingly.

3. Cross Pollination Studies

The percentage of cross-pollination under normal field conditions (with no provision of extra honey bees) was checked by tagging 200 to 300 florets on alternate days during the growing season on male sterile line 20 DRC, and on two plants each from tetraploid, hexaploid and Grimm. The pods from tagged florets were harvested separately as to date after maturity. The number of pods set per one hundred flowers tagged and number of seeds per pod were calculated for the growing season for the male sterile, tetraploids, hexaploids and Grimm, as an estimate of the proportion of self fertility for each group.

4. Statistical Analysis

The mean values of ten plants for each character were used for analysis of variance as randomized block design to test the differences among the genotypes of

tetraploid and hexaploid groups. Seed yield, forage yield and dry-matter per plant were used as criteria for selection of superior genotypes, using the least significant difference method. The variety Grimm was used as a check. Performances of the various crosses were compared with mid-parent, high-parent and Grimm for the three main characters used under selection, and was also taken as an indication of the heterotic effect in the crosses.

The diallel cross analysis was done following Griffing's (1956a) method assuming the mathematical model:

$$xij = u + gi + gj + sij + rij \text{ (if any)} + eijkl$$

where u is the population mean, gi (gj) is the general combining ability (GCA) for i^{th} (j^{th}) parents, sij is the specific combining ability (SCA) for the cross between i^{th} and j^{th} parents such that sij = sji, rij is reciprocal effects and eijkl is the environmental effect associated with the $ijkl^{th}$ individual observation. The following restrictions are imposed on the combining ability elements:

$$\sum_i gi = 0 \text{ and } \sum_i sij = 0 \text{ (for each j)}$$

Assuming the effects of genotypes and blocks as constant, Model I of Griffing's method was used for the combining ability analysis. Some of the other

assumptions were:

(i) All parental lines are equally heterozygous.

(ii) Lines are deliberately chosen on the basis of their previous performance.

(iii) Lines represent the selected population about which the inferences are to be made.

(iv) The objectives are to compare combining abilities of the parents when the parents themselves are used as testers.

Experimental method 1 (parents, one set of F_1's and reciprocals), method 2 (parents and one set of F_1's), method 3 (one set of F_1's and reciprocals) and method 4 (one set of F_1's but neither parents nor reciprocals) were used for the combining ability analysis wherever suited. In cases where the reciprocals were not available, it was assumed that there are no reciprocal differences. Here σ^2g, σ^2s and σ^2r stand for variances due to general and specific combining ability and reciprocal effects. The estimates of these effects are designated as $\hat{g}i$, $\hat{s}ij$ and $\hat{r}ij$, respectively.

The heritability for each character was computed in the broad sense as the ratio of genotypic and total phenotypic variance and in the narrow sense as the ratio of variance due to general combining ability attributed mainly to the additive gene effects and the total phenotypic variance (Lush 1949). The genetic gain

anticipated was calculated by multiplying the coefficient of heritability by the expected selection differential.

Along with variance, covariance analysis for each pair of variables measured was made. Simple, genotypic and phenotypic correlation coefficients were calculated using the formulae suggested by Fisher (1954) and Al-Jibouri, Miller and Robinson (1958), where the

$$\text{correlation coefficient, 'r'} = \frac{\text{cov xy}}{\sqrt{0^2 x \cdot 0^2 y}}$$

The variances and covariances of environmental, genotypic and phenotypic levels were used for the calculation of respective correlations. The sum of squares and the sum of cross products at error and genotypic levels were taken as error and phenotypic variances and covariances respectively. In the case of the genotypic correlation coefficient the sum of products and sum of squares at the error level were deducted from their respective values at the phenotypic level to obtain the genotypic covariances and variances. The partial correlation coefficients were calculated by standard formulae (Fisher 1944).

The method of discriminant function and the formula as suggested by Robinson et al. (1951) was adapted for construction of selection indices and for computing the expected genetic gain. The function may be defined

as

$$\Psi = b_1x_1 + b_2x_2 + b_3x_3 \ldots\ldots\ldots\ldots + b_nx_n$$

where Ψ is the total response and $b_1 \ldots\ldots b_n$ are the weights of $x_1 \ldots\ldots x_n$ characters.

The genetic advance

$$= 2.06 \cdot b_1yx_1 + b_2yx_2 \ldots\ldots\ldots + b_nyx_n$$

where yx_1, $yx_2 \ldots\ldots yx_n$ are the genotypic covariances between the above combinations and 2.06 is the selection differential in standard units for 5% selected.

EXPERIMENTAL RESULTS

A. POLLINATION AND FERTILITY

Percentage of cross-pollination under the growing conditions of Edmonton at the University of Alberta Parkland Farm was checked using male sterile line 20 DRC, which, when crossed, showed 84.4% pod setting, indicating its high degree of cross compatibility. Racemes on these plants randomly located throughout the growing area were tagged during the growing season. After maturity, pods were harvested from these tagged racemes from 20 DRC, two tetraploids, two hexaploids and two Grimm plants. The results are presented in Table 1.

From the cross pollination data noted on male sterile line 20 DRC, it is evident that there was very low percent (1.22%) of out-crossing in Edmonton conditions, suggesting the high degree of self fertility in these tetraploid (approximately 30%-40%) and hexaploid (approximately 29%) lines which is also higher than the check variety Grimm (9%). Since the lines were previously selected for the seed setting ability under these conditions in scarcity of pollinating bees, it may be concluded that selection for higher pod set is possible with this material. Similar results were also reported by Kirk (1933), Tysdal and Clark (1934), Fryer (1939) and Lesins (1950).

Table 1. The cross pollination data on tetraploid, hexaploid, Grimm and the male sterile line 20 DRC.

Item	20 DRC	Tetra 1	Tetra 2	Hexa 1	Hexa 2	Grimm 1	Grimm 2
No. of flowers tagged	3110	3326	2558	2514	1647	3413	2347
No. of pods	38	1344	778	724	492	305	222
No. of seeds	181	2539	1501	1596	854	486	550
% of flowers forming pod	1.22	40.0	30.41	28.79	29.87	8.93	9.45
Seeds per pod	4.76	1.889	1.92	2.20	1.73	1.59	2.47
Seeds per flower	0.058	0.7633	0.586	0.634	0.518	0.1423	0.234

STUDY OF QUANTITATIVE CHARACTERS

The quantitative characters mentioned earlier were noted in both the tetraploids and the hexaploids. They will be tested separately from here on, according to their ploidy level.

The character measurement means of the genotypes are given in Table I (I-1 to I-15) for tetraploids and in Table II for hexaploids (both tables in appendix). Table 2 shows the analysis of variance for the fifteen characters studied in the tetraploid group. All the 'F' values were found to be highly significant (at 1% probability), implying reliable differences among the genotypes. Similarly, Table 3 shows the analysis of variance for the seven characters studied in the hexaploid group. It is evident from this table that most characters showed a highly significant 'F' value except first cutting and dry matter content which were significant at the 5% level of probability

Table 2. The analysis of variance for the characters studied in the tetraploids.

	Characters	Mean squares due to			F-Value
		Blocks	Genotypes	Error	
T1	First cut	0.4409	0.0872	0.0244	3.5740**
T2	Second cut	0.0484	0.0452	0.0075	5.9930**
T3	Forage yield	0.3954	0.2239	0.0460	4.8611**
T4	Seed yield	282.7390	315.6050	43.9976	7.1732**
T5	Seeds/pod	4.0803	0.5425	0.1336	4.0608**
T6	Dry matter/plant	0.0149	0.0085	0.0024	3.5500**
T7	Forage yield in establishment year	0.6421	0.1278	0.0133	9.5412**
T8	Leaf area	1.4235	0.1434	0.0212	6.7380**
T9	Leaf length	0.8417	0.0583	0.0076	7.6730**
T10	Frost resistance	0.9291	0.2793	0.0433	6.4400**
T11	Plant vigor	0.2258	0.2580	0.0467	5.5240**
T12	Growth habit	0.1169	0.1207	0.0143	8.4377**
T13	Plant height	109.8290	257.9390	30.7430	8.3900**
	D.F.	3	48	144	
T14	% pod set during crossing	-	54.5350	10.7060	5.0930**
T15	No. of seeds per pod crossed	-	5.0110	0.9600	5.2190**

** Significant at 1% level of probability.

Table 3. The analysis of variance for the characters studied in the hexaploids.

Characters		Mean squares due to Blocks	Genotypes	Error	F-Value
D.F.		4	14	49	
X1	First cut	0.0242	0.0382	0.0187	2.0789*
X2	Second cut	0.0177	0.0833	0.0064	12.9092**
X3	Forage yield	0.5080	0.2142	0.0307	6.9697**
X4	Seed yield	5.8929	82.2181	4.3492	18.9040**
X5	Seeds/pod	0.2550	0.4525	0.0604	7.4870**
X6	Dry matter per plant	0.0299	0.0105	0.0063	1.6524*
X7	Plant height	174.6090	116.6090	18.2110	6.4030**

* Significant at 5% level of probability.

** Significant at 1% level of probability.

Further selection was made in tetraploids. The selection was based on three characters, namely seed yield, dry matter per plant and forage yield. The least significant difference method was used to select out the superior genotypes where the variety Grimm was used as a check. The selected genotypes are underlined in Tables I-3, I-4, I-6 (appendix).

B. COMPARISON OF SINGLE CROSS PROGENIES WITH THEIR PARENTS AND THE VARIETY GRIMM

(a) Tetraploids

A comparison of single cross progenies with mid-parent, high-parent and the check variety Grimm was made for the three main characters, viz., seed yield, forage yield and dry matter yield per plant. The comparison was made in terms of the performance of progenies as percent of the mid-parent, the high-parent and Grimm.

Table 4 shows the results of seed yield per plant. The single cross progenies produced an average of 371.99% more seed than the mid-parent and 287.54% more than their high-parent. It can also be noted that they had 377.43% more seed yield than variety Grimm. The single crosses 5 x 242, 16 x 242 and 201 x 242 seem to be highly promising having values of 611.21%, 570.19% and 567.57%, respectively, more than Grimm. Parental lines 5, 201 and 242 had yields of 152.77%, 156.10% and 169.79% of the check variety Grimm. From this table it is clear that all single crosses show a high degree of heterosis.

Table 5 shows the results of forage yield per plant of the single cross progenies of selfed parents and of the check variety Grimm. The mean of the single crosses shows that they produced 126.16% of mid-parent, 114.60% of high-parent and 128.50% of the check. All these progenies

Table 4. Seed yield (T4) per plant for Grimm, selfed parents and single cross progenies and as % of mid-parent, high-parent and Grimm.

Line/Progeny	Seed yield (gm.)	% Mid-parent	% High-parent	% Grimm
Grimm	5.770	-	-	100.00
5	8.815	-	-	152.77
16	6.132	-	-	106.27
34	4.372	-	-	75.77
63	3.475	-	-	60.23
67	2.200	-	-	38.12
201	9.007	-	-	156.10
242	9.797	-	-	169.79
5 x 16	19.796	264.90	224.57	343.08
5 x 34	14.770	224.02	167.55	255.97
5 x 63	18.115	294.79	205.50	313.95
5 x 67	12.076	219.28	136.99	209.28
5 x 201	20.822	233.66	231.17	360.86
5 x 242	35.267	378.97	359.97	611.21
16 x 34	13.281	252.87	216.58	230.17
16 x 63	18.811	391.67	306.76	326.01
16 x 67	25.200	604.89	410.95	436.74
16 x 201	24.298	321.01	269.76	421.10
16 x 242	32.900	413.10	335.81	570.19
34 x 63	24.492	624.31	560.20	424.47
34 x 67	13.679	416.28	313.28	237.07
34 x 201	13.277	198.49	147.40	230.10
34 x 242	23.517	331.97	240.04	407.57
63 x 67	20.063	858.49	577.35	347.71
63 x 201	24.605	394.24	273.17	426.42
63 x 242	25.973	391.39	265.11	450.13
67 x 201	18.381	328.05	204.07	318.56
67 x 242	25.267	421.25	257.90	437.90
201 x 242	32.749	348.32	334.27	567.57
Mean (crosses)	21.778	371.99	287.54	377.43

Table 5. Forage yield 1969 (T3) per plant for Grimm, selfed parents and single cross progenies and as % of mid-parent, high-parent and Grimm.

Line/Progeny	Forage yield (kg)	% Mid-parent	% High-parent	% Grimm
Grimm	1.412	-	-	100.00
5	1.117	-	-	79.10
16	1.720	-	-	121.81
34	1.290	-	-	91.35
63	1.367	-	-	96.81
67	1.265	-	-	89.58
201	1.923	-	-	136.18
242	1.427	-	-	101.06
5 x 16	1.823	128.56	105.98	121.10
5 x 34	1.602	133.16	124.18	113.45
5 x 63	1.648	123.91	120.55	116.71
5 x 67	1.539	129.21	121.66	108.99
5 x 201	1.792	117.89	93.18	126.91
5 x 242	1.893	148.82	132.65	134.06
16 x 34	1.809	120.19	105.17	128.11
16 x 63	1.744	113.02	101.39	123.51
16 x 67	1.884	126.22	109.53	133.42
16 x 201	1.950	107.08	101.40	138.10
16 x 242	1.988	126.38	115.58	140.79
34 x 63	2.009	151.39	146.96	142.28
34 x 67	1.658	129.83	128.52	117.42
34 x 201	1.874	116.68	97.45	132.71
34 x 242	1.683	123.93	117.93	119.19
63 x 67	1.664	126.44	121.72	117.84
63 x 201	1.864	113.31	96.93	132.01
63 x 242	1.813	129.77	127.04	128.39
67 x 201	1.902	119.32	98.90	134.70
67 x 242	1.815	134.84	127.18	128.54
201 x 242	2.168	129.43	112.74	153.54
Mean (crosses)	1.815	126.16	114.60	128.56

exhibited heterosis when considered at mid-parent value. Most of them, with the exception of 5 x 201, 63 x 201, 34 x 201 and 67 x 201, were superior to their high-parent. All crosses were found to be superior to the check for this character.

On the basis of the performance of the parental lines, it may be said that lines 16 and 201 are better than the check and line 242 compares well with it as they yielded 121.81%, 136.18% and 101.06%, respectively, of Grimm.

The results pertaining to the character dry matter per plant, are presented in Table 6. The parents as judged by their self progenies do not appear to be superior to Grimm with respect to this character, though line 201 could be considered as equal to it. It may be noted that this line was highest in forage yield (Table 5). Most of the single cross progenies exhibit heterosis as their values are statistically higher than those of the high-parent with the exception of crosses 16 x 63, 16 x 201, 34 x 201, 63 x 242, which show complete dominance (their values are equal to the high-parent) and cross 63 x 201 which shows partial dominance (its value is between the mid-parent and high-parent.

On the average, 123.58% and 113.69% yield increase was found for the single crosses over their mid-parent and high-parent values, respectively. They were also found to be 104.46% superior over the check variety Grimm.

Table 6. Dry matter yield (T6) per plant for Grimm, selfed parents and single cross progenies and as % of mid-parent, high-parent and Grimm.

Line/Progeny	Dry matter (kg.)	% Mid-parent	% High-parent	% Grimm
Grimm	0.315	-	-	100.00
5	0.315	-	-	83.55
16	0.333	-	-	88.32
34	0.338	-	-	89.65
63	0.237	-	-	62.86
67	0.287	-	-	76.12
201	0.385	-	-	102.13
242	0.347	-	-	92.04
5 x 16	0.420	129.62	126.12	111.40
5 x 34	0.405	124.23	119.82	107.42
5 x 63	0.359	130.07	113.96	95.22
5 x 67	0.402	133.55	127.61	106.63
5 x 201	0.410	117.14	106.42	108.75
5 x 242	0.421	127.19	121.32	111.67
16 x 34	0.376	112.23	111.24	99.73
16 x 63	0.337	118.24	101.20	89.38
16 x 67	0.423	136.45	127.02	112.20
16 x 201	0.392	109.19	102.07	103.97
16 x 242	0.400	117.64	115.27	106.10
34 x 63	0.369	128.57	109.17	97.87
34 x 67	0.432	138.46	127.81	114.58
34 x 201	0.384	106.37	99.74	101.85
34 x 242	0.434	126.90	125.07	115.12
63 x 67	0.376	143.51	131.01	99.73
63 x 201	0.363	116.72	94.28	96.28
63 x 242	0.350	119.86	100.86	92.83
67 x 201	0.412	122.61	107.01	109.28
67 x 242	0.392	123.65	112.96	103.97
201 x 242	0.414	113.11	107.53	109.81
Mean (crosses)	0.394	123.58	113.69	104.46

(b) Hexaploids

A comparison of single cross progenies with mid-parent, high-parent and Grimm (standard variety) was made for the main characters studied, viz., seed yield, forage yield and dry matter per plant. This comparison was based on the performance of progenies as percent of the mid-parent, the high-parent and Grimm.

Table 7 shows the seed yield per plant for the parents, progenies and Grimm. The single cross progenies out-yielded the mid-parent and the high-parent on the average by 279.57% and 240.63%, respectively, and were superior to Grimm by 234.05%. These lines had previously been selected for this character. Except cross 2 x 3, all others exhibited heterosis on both the mid-parent and high-parent basis. All the crosses except 2 x 3 were superior to the check. It seems probable that the seed yield could be improved by selecting superior lines and utilizing them in various hybrid combinations, as the single crosses in general showed superiority over the parents.

The forage yield data are presented in Table 8. The manifestation of heterosis in single cross progenies is quite evident when it is calculated on the mid-parent and the high-parent basis, with the exception of cross 2 x 3. The magnitude of this heterotic effect was less than that of the seed

Table 7. The seed yield (X4) for Grimm, selfed parents, and their single cross progenies and as % of mid-parent, high-parent and Grimm.

Line/Progeny	Seed yield (gm.)	% Mid-parent	% High-parent	% Grimm
Grimm	3.548	-	-	100.00
1	2.798	-	-	78.86
2	1.836	-	-	51.74
3	3.249	-	-	91.57
4	4.994	-	-	140.75
5	2.604	-	-	73.39
Single crosses				
1 x 2	3.260	156.23	129.37	102.02
1 x 3	6.266	207.27	192.85	176.60
1 x 4	9.625	247.04	192.73	271.27
1 x 5	14.731	545.39	526.48	415.19
2 x 3	1.920	75.53	59.09	45.11
2 x 4	6.747	197.56	135.10	190.16
2 x 5	10.252	461.80	393.70	288.95
3 x 4	5.905	143.29	118.24	166.43
3 x 5	16.612	567.73	511.29	468.20
4 x 5	7.367	193.91	147.51	207.63
Mean (single-crosses)	8.304	279.57	240.63	234.05

Table 8. Forage yield (X3) for Grimm, selfed parents and their single cross progenies and as % of mid-parent, high-parent and Grimm.

Line/Progeny	Forage yield (kg.)	% Mid-parent	% High-parent	% Grimm
Grimm	1.631	-	-	100.00
1	0.883	-	-	54.13
2	0.801	-	-	49.11
3	0.800	-	-	49.04
4	0.727	-	-	44.57
5	0.988	-	-	60.57
Single crosses				
1 x 2	0.902	107.12	102.15	54.30
1 x 3	0.894	106.30	101.24	54.81
1 x 4	0.998	123.97	113.02	61.18
1 x 5	1.339	143.21	135.52	82.09
2 x 3	0.513	64.12	64.04	31.45
2 x 4	1.082	141.62	135.08	66.33
2 x 5	1.231	137.69	124.59	75.47
3 x 4	0.880	115.33	110.00	53.95
3 x 5	1.357	151.78	137.34	83.20
4 x 5	1.145	133.60	115.89	70.20
Mean (single-crosses)	1.034	122.51	113.88	63.29

Table 9. The dry matter yield (X6) of Grimm, selfed parents and their single cross progenies and as % of mid-parent, high-parent and Grimm.

Line/Progeny	Dry matter (kg.)	% Mid-parent	% High-parent	% Grimm
Grimm	0.434	-	-	100.00
1	0.137	-	-	32.56
2	0.154	-	-	35.56
3	0.171	-	-	39.40
4	0.137	-	-	31.56
5	0.207	-	-	47.69
Single crosses				
1 x 2	0.167	115.17	108.44	38.47
1 x 3	0.149	96.75	87.13	34.33
1 x 4	0.177	129.19	129.19	40.61
1 x 5	0.211	122.67	101.93	48.61
2 x 3	0.317	195.67	185.38	73.04
2 x 4	0.203	140.00	131.81	46.77
2 x 5	0.226	125.55	109.17	52.07
3 x 4	0.142	92.29	83.04	32.71
3 x 5	0.270	142.85	130.43	62.21
4 x 5	0.202	117.44	97.58	46.54
Mean (single-crosses)	0.206	127.74	116.41	47.55

yield. The lines had been selected for the seed yield and the forage yield was a secondary character, except for line 5 which parents were selected also for forage yield. Its influence in crosses is obvious.

The single crosses out-yielded the parental lines on the average by 122.51% and 113.88% when compared to mid-parent and high-parent, respectively, but yielded only 63.29% of the check variety Grimm.

Table 9 shows the dry matter yield per plant of parental lines, their single crosses and Grimm. The progenies yielded on the average, 127.74% and 116.41% more than their mid-parents and high-parents, respectively, but only 47.55% of Grimm. Thus, though the progenies seem to be quite superior to the parents all of them yielded considerably less than the variety Grimm. Highest manifestation of vigor was shown by cross 2 x 3 followed by 3 x 5 and 2 x 4. In general, line 5 had a marked effect in contributing to the positive expression of this character. The inconsistency between forage yield and dry matter yield of cross 2 x 3 may be due to the fact that two different sets of replications were involved, and leaf shed may have taken place.

Inbreeding depression, the reverse of hybrid vigor, was observed in the selfed progenies of alfalfa by Kirk (1927), Wilsie (1958), Koffman and Wilsie (1961) and others. Heterosis, on the other hand, is also quite

commonly mentioned in the literature, though values as high as 600%, as was noted for seed yield in tetraploids, are not very common. However, the parental lines were previously selected for this character and thus high values like these could be expected.

Though Nilsson and Anderson (1941) noted the increased vegetative vigor in hexaploids, breeding of hexaploids was not found to be very encouraging due to the low fertility of such plants (Lesins 1952). Lesins, Singh and Baysal (1969) have reported that selection for the increased seed yield is possible. The inbreeding depression and hybrid vigor studies in hexaploid populations are almost nonexistent. From this experiment it seems that the extent of heterosis is more for the characters used in the previous selection in hexaploids as was also noted in tetraploids.

As mentioned earlier, a number of quantitative characters, thought to be of importance for the selection program, were studied during two growing seasons. The evaluation of experimental results obtained for these characters will be considered for the hexaploids and tetraploids separately.

C. COMBINING ABILITY

(a) Tetraploids

Fifteen quantitative characters noted on the diallel crosses of seven selected tetraploid lines were analyzed by Griffing's method of diallel cross analysis for the combining ability and reciprocal differences.

Table 10 shows that the variance due to general and specific combining ability were highly significant for the characters: first cutting (T1), second cutting (T2), forage yield 1969 (T3), seed yield (T4), seeds per pod (T5), dry matter per plant (T6), forage yield in the year of establishment, 1968 (T7), leaf area (T8), leaf length (T9), frost resistance (T10), plant vigor (T11), plant height (T13) and percentage of pod set during crossing (T14). The growth habit (T12) was found to be significant for general and specific combining ability variances only at the 5% level of probability. The variance due to general combining ability was also noted

Table 10. The combining ability analysis of the characters studied in tetraploid diallel crosses.

Characters	Sources of Variation			
	GCA ($\sigma^2 g$)	SCA ($\sigma^2 s$)	Reciprocal effects ($\sigma^2 r$)	Residual
D.F.	6	21	21	144
T1	0.0648**	3.9740**	0.0098	0.0244
T2	0.0306**	3.3350**	0.0048	0.0075
T3	0.1560**	14.5900**	0.0218	0.0462
T4	178.8500**	1936.8900**	22.6560	43.9970
T5	0.6030**	48.0860**	0.0225	0.1336
T6	0.0049**	0.7080**	0.0024	0.0024
T7	0.1750**	5.6590**	0.0103	0.0133
T8	0.1980**	27.0700**	0.0153	0.0212
T9	0.0851**	27.0680**	0.0046	0.0076
T10	0.2855**	295.1400**	0.0191	0.0433
T11	0.1910**	256.9700**	0.3117**	0.0467
T12	0.2010*	214.3300*	0.0036	0.0143
T13	416.4890**	54534.5000**	12.2800	30.7430
D.F.	6	14	21	41
T14	468.4000**	91.5800**	99.2000**	10.7060
T15	3.9860**	0.5573	0.7449	0.9600

* Significant at 5% level of probability.

** Significant at 1% level of probability.

T1 = First cut, T2 = Second cut, T3 = Forage yield, T4 = Seed yield, T5 = Seeds per pod, T6 = Dry matter per plant, T7 = Forage yield in the year of establishment, 1968, T8 = Leaf area, T9 = Leaf length, T10 = Frost resistance, T11 = Plant vigor, T12 = Growth habit, T13 = Height at maturity, T14 = Percentage of pod set during crossing, T15 = Seeds per pod set during crossing.

to be highly significant for number of seeds per pod set during crossing (T15), but its value for specific combining ability was not significant.

It is also evident from Table 10 that the variances due to reciprocal differences for all but plant vigor (T11) and percentage of pod set during crossing (T14), were not significantly different from zero.

The heritability in broad and narrow sense was calculated for all the characters. The estimates of tetraploids are presented in Table 27.

Further description is given below characterwise.

1. First cutting (T1)

The first cutting ~~It~~ represents the total vegetative growth in the spring of Edmonton (Alberta) and was recorded as the fresh weight of plants cut in the first week of July 1969.

The estimates of general combining ability suggest that lines 201, 16 and 242 have positive and comparatively higher values for general combining ability (Table 11). Table 12 shows that crosses 34 x 63, 5 x 242 and 201 x 242 have higher and positive values of specific combining ability. In most cases the specific combining ability estimates were found to be higher than the general combining ability.

The broad sense heritability estimate for the first

Table 11. The estimates of general combining ability ($\hat{g}i$) of the tetraploid lines for various characters.

Variables	Parental Lines						
	5	16	34	63	67	201	242
T1	-0.070	0.086	-0.031	-0.052	-0.047	0.093	0.022
T2	-0.057	0.001	-0.036	0.018	-0.036	0.076	0.034
T3	-0.130	0.085	-0.063	-0.031	-0.085	0.169	0.061
T4	-1.103	0.434	-4.285	-0.037	-2.931	1.050	6.870
T5	-0.079	0.067	0.330	-0.166	-0.255	-0.091	0.195
T6	0.007	-0.001	0.008	-0.042	0.006	0.011	0.011
T7	-0.065	-0.004	0.007	-0.087	-0.088	0.235	0.002
T8	-0.009	-0.152	-0.083	-0.063	0.155	0.155	0.004
T9	0.039	-0.107	-0.091	0.075	0.069	0.057	-0.042
T10	-0.011	0.050	-0.142	-0.134	-0.083	0.128	0.295
T11	-0.098	0.051	-0.200	-0.025	0.034	0.119	0.118
T12	0.217	0.012	-0.010	0.068	-0.086	-0.159	-0.042
T13	6.972	-3.397	6.002	-5.456	4.172	-4.013	-4.285
T14	-6.298	5.598	-7.969	2.018	-7.066	6.531	7.183
T15	0.295	0.283	-0.513	-0.081	-0.349	0.302	0.265

T1 = First cut, T2 = Second cut, T3 = Forage yield, T4 = Seed yield, T5 = Seeds per pod, T6 = Dry matter per plant, T7 = Forage yield in the year of establishment, T8 = Leaf area, T9 = Leaf length, T10 = Frost resistance, T11 = Plant vigor, T12 = Growth habit, T13 = Height at maturity, T14 = Percentage of pod set during crossing, T15 = Seeds per pod set during crossing.

Tables 12 and 13:

Estimates of specific combining ability ($\hat{s}ij$), general combining ability ($\hat{g}i$), and reciprocal effects ($\hat{r}ij$) for various genotypes of tetraploids.

Table 12. First cut (Growth in spring 1969) (T1)

	♀ Parents	$\hat{s}ij$ 5	16	34	63	67	201	242	$\hat{g}i$
	5	–	-0.064	0.019	0.029	-0.022	-0.008	0.127	-0.070
	16	0.122	–	0.007	-0.011	-0.074	-0.140	0.070	0.086
	34	-0.015	0.004	–	0.193	0.029	-0.002	-0.068	-0.031
$\hat{r}ij$	63	0.016	-0.015	0.091	–	0.071	-0.017	0.011	-0.052
	67	-0.098	0.123	0.080	0.004	–	0.059	0.056	-0.047
	201	0.028	0.076	0.107	0.088	0.041	–	0.106	0.093
	242	-0.081	-0.078	-0.031	-0.043	-0.044	0.056	–	0.022

Table 13. Second cut (Growth in fall 1969) (T2)

	5	–	0.041	0.019	0.023	0.013	0.003	0.080	-0.057
	16	0.064	–	0.024	-0.060	0.066	0.004	0.018	0.001
	34	-0.018	-0.112	–	0.159	0.022	0.015	-0.086	-0.036
$\hat{r}ij$	63	0.000	0.007	0.061	–	0.015	0.001	0.022	0.018
	67	0.015	0.026	0.063	-0.004	–	-0.001	0.026	-0.036
	201	0.047	0.055	0.022	0.066	-0.006	–	0.079	0.076
	242	-0.034	-0.009	0.065	-0.056	-0.049	-0.059	–	0.034

cut was 72% in comparison to 1.39% of narrow sense heritability (Table 27). This indicates that the major part of genetic variances for this character are due to dominance and epistatic interaction effects.

2. <u>Second cutting</u> (T2)

It represents the vegetative growth after the first cutting and was measured as fresh weight of plants cut during the first week of September 1969.

The variance and estimates of specific combining ability were noted to be higher than the general combining ability. Lines 201 and 242 were found to have comparatively higher values for general combining ability as is shown in Table 11 and Table 13. It is also evident from Table 13 that crosses 34 x 63, 5 x 242 and 201 x 242 have higher specific combining ability effects than the rest and their selection is expected to be effective if this character is taken as a criterion for selection.

The value of broad sense heritability (70.79%) was found to be quite high in comparison to its narrow sense value (0.91%), which shows that the genetic variance for this character consists mostly of dominance and nonallelic interaction components.

Tables 14 and 15:

Estimates of specific combining ability ($\hat{s}ij$), general combining ability ($\hat{g}i$), and reciprocal effects ($\hat{r}ij$) for various genotypes of tetraploids.

Table 14. Total forage yield 1969 (T3)

	♀ Parents	$\hat{s}ij$ 5	16	34	63	67	201	242	$\hat{g}i$
	5	-	0.107	0.034	0.049	-0.006	-0.002	0.202	-0.130
	16	0.187	-	0.027	-0.071	0.124	-0.059	0.082	0.085
	34	-0.034	-0.107	-	0.342	0.046	0.012	-0.115	-0.063
$\hat{r}ij$	63	0.014	-0.010	0.152	-	0.020	-0.030	0.023	-0.031
	67	0.113	0.150	0.143	-0.008	-	0.062	0.080	-0.085
	201	0.078	0.131	0.129	0.142	0.035	-	0.183	0.164
	242	-0.116	-0.087	0.034	-0.098	-0.095	-0.003	-	0.060

Table 15. Seed yield per plant 1969 (T4)

	5	-	0.839	0.531	-0.372	-3.517	1.249	9.874	-1.103
	16	4.659	-	-2.494	-1.212	8.071	3.189	5.970	0.434
	34	1.610	-2.131	-	9.187	1.269	-3.114	1.306	-4.285
$\hat{r}ij$	63	0.915	0.754	-1.095	-	3.404	5.556	-0.486	-0.037
	67	0.931	3.355	2.497	-3.163	-	0.636	1.701	-2.931
	201	4.187	-4.923	3.575	-1.355	-2.721	-	5.203	1.050
	242	1.817	-5.585	-7.430	1.603	1.360	-4.517	-	6.870

3. Forage yield (T3)

It represents the total vegetative growth of the plant during the growing season and was recorded as the total of two cuttings taken during the period.

Lines 201, 242 and 16 seem to have better general combining ability as the estimates of general combining ability for these lines is higher than the rest and positive. Table 14 shows that crosses 34 x 63, 5 x 242 and 201 x 242 exhibit comparatively higher specific combining ability. The estimates of specific combining ability were found to have higher values than those of general combining ability.

The heritability estimate taken as the ratio of additive and total phenotypic variance was very low (1.52%), as compared to its broad sense estimate (79.45%). This observation is in agreement with the combining ability estimates and suggests that the major part of the genetic variance for this character consists of heritable but not fixable components of variation.

4. Seed yield (T4)

Estimates for the general and specific combining ability for each line and each cross (Tables 11 and 15) show that lines 242, 201 and 16 have higher values for general, and crosses 5 x 242, 34 x 63, 16 x 242, 63 x 201,

16 x 67 and 201 x 242 have higher values for specific combining ability. It could be noted here that though lines 34 and 63 had negative and low values of general combining ability, their cross 34 x 63 shows the higher value for specific combining ability.

The character in itself seems to be highly heritable as its broad sense heritability was found to be 86.05%, but its fixable part appears to be relatively low since its narrow sense heritability was noted to be 8.19%. This again follows the findings of combining ability analysis and suggests that the greater proportion of genetic variance is due to allelic and nonallelic interactions.

5. Seeds per pod (T5)

Estimates of general and specific combining ability are given in Tables 11 and 16. It is obvious that lines 34 and 242 have comparatively higher values for general combining ability, and crosses 34 x 67, 5 x 242 and 5 x 34 have higher values for specific combining ability. Though lines 34 and 242 showed higher general combining ability, the cross 34 x 242 was not found to have higher specific combining ability.

The broad sense heritability (75.37%) was considerably higher than the narrow sense heritability (1.24%).

Tables 16 and 17:

Estimates of specific combining ability ($\hat{s}ij$), general combining ability ($\hat{g}i$), and reciprocal effects ($\hat{r}ij$) for various genotypes of tetraploids.

Table 16. Seeds per pod (T 5)

	♀ Parents	$\hat{s}ij$							$\hat{g}i$
		5	16	34	63	67	201	242	
	5	-	-0.149	0.251	0.064	-0.305	0.192	0.371	-0.079
	16	0.002	-	-0.060	0.058	0.047	-0.027	0.017	0.067
	34	-0.086	0.044	-	0.134	0.409	-0.082	0.016	0.330
$\hat{r}ij$	63	0.208	0.128	-0.007	-	0.059	0.245	-0.067	-0.166
	67	0.004	-0.076	-0.147	-0.007	-	0.009	0.021	-0.255
	201	0.021	-0.073	-0.176	-0.114	-0.155	-	0.084	-0.091
	242	0.139	-0.008	-0.085	0.108	0.096	-0.142	-	0.195

Table 17. Dry matter per plant (T 6)

	5	-	0.030	0.007	0.010	0.006	0.009	0.020	0.007
	16	0.011	-	-0.015	-0.004	0.034	-0.002	0.007	-0.001
	34	0.003	0.047	-	0.019	0.035	-0.018	0.032	0.008
$\hat{r}ij$	63	0.020	0.027	-0.031	-	0.029	0.011	-0.002	-0.042
	67	-0.031	-0.003	0.025	0.013	-	0.017	-0.008	0.006
	201	0.025	-0.004	0.031	0.017	0.002	-	0.009	0.011
	242	0.018	-0.031	-0.043	0.006	-0.001	-0.013	-	0.011

6. Dry matter yield per plant (T6)

In general, the estimates of general and specific combining ability effects were quite low. As is evident from Table 11, the general combining ability effects for lines other than 63 and 16 were, although low, positive. The crosses 34 x 67, 16 x 67, 34 x 242, 5 x 16, 63 x 67, 5 x 242 and 34 x 63 were comparatively higher in the specific combining ability estimates than the rest(Table 17).

The character was recorded on the same plants as seed yield, and therefore was taken as an indication of vegetative growth of these plants. Along with seed yield, its selection for dry matter yield was supposed to produce plants of high vegetative yield.

The narrow sense heritability (0.61%) was found to be very low in comparison to the broad sense heritability (71.90%).

7. Forage yield in the year of establishment (T7)

On the basis of individual estimates (Table 18), line 201 was found to have the highest general combining ability value. The specific combining ability values were comparatively higher for the crosses 5 x 242 and 34 x 63. Crosses showing high specific combining ability did not necessarily have parents showing higher general combining ability. The specific combining ability variance was considerably higher (32.3 times)

Tables 18 and 19:

Estimates of specific combining ability ($\hat{s}ij$), general combining ability ($\hat{g}i$), and reciprocal effects ($\hat{r}ij$) for various genotypes of tetraploids.

Table 18. Forage yield (1968 - year of establishment) (T7)

	♀ Parents	$\hat{s}ij$							$\hat{g}i$
		5	16	34	63	67	201	242	
	5	-	0.031	0.012	0.049	-0.028	0.027	0.098	-0.065
	16	-0.016	-	0.062	-0.091	0.053	-0.046	0.028	-0.004
	34	0.047	-0.118	-	0.092	0.048	-0.021	-0.036	0.007
$\hat{r}ij$	63	0.078	0.099	0.021	-	0.031	0.023	0.067	-0.087
	67	0.115	-0.019	0.044	0.026	-	0.046	0.016	-0.088
	201	0.102	0.044	0.137	0.106	0.035	-	0.027	0.235
	242	-0.028	-0.007	-0.039	0.051	-0.025	-0.103	-	0.002

Table 19. Leaf area (middle leaflet) (T8)

	5	-	0.053	0.007	-0.031	0.028	0.055	-0.040	-0.009
	16	0.012	-	-0.042	-0.038	0.155	-0.118	0.099	-0.152
	34	-0.020	0.022	-	0.105	-0.111	0.032	0.041	-0.083
$\hat{r}ij$	63	-0.070	0.137	0.011	-	0.090	0.088	-0.065	-0.063
	67	0.128	0.064	0.123	0.039	-	-0.059	0.030	+0.155
	201	0.028	0.081	0.155	0.169	-0.049	-	-0.036	0.155
	242	0.072	0.044	-0.060	-0.020	-0.020	-0.108	-	0.004

than the general combining ability. Similarly, the broad sense heritability (89.6%) was higher (29.9 times) than the narrow sense heritability (2.98%). This suggests that the genetic interaction components constitute the major part of the variation for this character.

8. Leaf area (T8)

The general combining ability estimates for the lines (Table 11) suggests that lines 67 and 201 have higher value for general combining ability and crosses 16 x 67, 34 x 63, 63 x 201 and 63 x 67 are among the high specific combining ability combinations (Table 19). The cross 34 x 63 shows high specific combining ability, although the parents have low general combining ability.

The broad sense heritability (85.21%) was approximately 19 times greater than the narrow sense heritability (4.37%).

9. Leaf length (T9)

The estimates of general and specific combining ability (Tables 11 and 20) suggest that lines 63, 67, 201 and 5 are comparatively better in their general combining ability. The crosses 16 x 242 and 63 x 201 have higher specific combining ability. In general, these estimates were quite low in their magnitude.

Tables 20 and 21:

Estimates of specific combining ability ($\hat{s}ij$), general combining ability ($\hat{g}i$), and reciprocal effects ($\hat{r}ij$) for various genotypes of tetraploids.

Table 20. Leaf length (middle leaflet) (T9)

♀ Parents	$\hat{s}ij$ 5	16	34	63	67	201	242	$\hat{g}i$
5	-	0.011	0.010	-0.026	0.005	0.042	0.006	0.039
16	-0.015	-	-0.005	0.036	0.035	-0.033	0.086	-0.107
34	0.000	0.000	-	0.038	-0.066	-0.008	0.021	-0.091
$\hat{r}ij$ 63	-0.020	0.075	-0.005	-	-0.048	0.066	-0.050	0.075
67	0.105	0.010	0.085	-0.005	-	-0.059	0.016	0.069
201	0.020	0.070	0.080	0.007	-0.050	-	0.018	0.057
242	-0.015	0.020	-0.030	-0.035	-0.025	-0.045	-	-0.042

Table 21. Frost resistance (T10)

5	-	-0.010	0.025	0.133	-0.023	0.071	0.174	-0.113
16	-0.025	-	0.038	0.016	-0.800	-0.026	0.017	0.050
34	-0.930	-0.190	-	0.152	0.012	-0.015	-0.096	-0.142
$\hat{r}ij$ 63	0.065	0.130	-0.065	-	0.079	-0.133	0.021	-0.134
67	-0.010	0.180	0.155	-0.020	-	0.067	0.060	-0.083
201	0.060	0.150	0.180	0.070	0.080	-	0.169	0.128
242	-0.005	-0.050	-0.005	-0.015	0.000	-0.080	-	0.295

The broad sense heritability was found to be 86.96% but the narrow sense heritability estimate was found to be only 0.313%.

10. Frost Resistance (T10)

The estimates of general combining ability (Table 11) and specific combining ability (Table 21) show that the lines 242 and 201 have high general combining ability and could be expected to show the frost resistance in various hybrid combinations. The crosses 5 x 242, 201 x 242 and 34 x 63 have higher values for specific combining ability. It could be noted here that lines 34 and 63, having the lowest values of general combining ability, show quite high specific combining ability in the combination 34 x 63.

The broad sense heritability (84.49%) was quite high in comparison to its narrow sense value (0.096%) and suggests that the dominance and epistatic components of variation contribute the major part of the genetic variance. Similar conclusions can also be made from the combining ability analysis.

11. Plant Vigor (T11)

The diallel cross analysis, as mentioned earlier, showed that the variances due to general and specific combining ability, and reciprocal differences are sig-

Tables 22 and 23:

Estimates of specific combining ability ($\hat{s}ij$), general combining ability ($\hat{g}i$), and reciprocal effects ($\hat{r}ij$) for various genotypes of tetraploids.

Table 22. Plant vigor (T 11)

	♀ Parents	$\hat{s}ij$ 5	16	34	63	67	201	242	$\hat{g}i$
	5	-	0.193	0.155	0.049	0.000	-0.067	0.176	-0.098
	16	0.105	-	-0.110	-0.004	0.291	-0.123	0.132	0.051
	34	0.035	-0.055	-	0.316	-0.038	0.052	0.013	-0.200
$\hat{r}ij$	63	0.005	0.100	0.100	-	0.028	0.033	-0.046	-0.025
	67	0.165	-0.004	0.185	-0.025	-	0.069	-0.106	0.034
	201	0.060	-0.135	0.310	0.235	-0.180	-	0.084	0.119
	242	0.065	-0.030	0.090	-0.015	-0.095	-0.020	-	0.118

Table 23. Growth Habit (T12)

	5	-	0.031	-0.062	0.185	-0.066	-0.038	-0.066	0.217
	16	-0.015	-	0.038	-0.015	0.029	-0.068	-0.011	0.012
	34	-0.005	0.035	-	-0.033	0.001	0.034	0.021	-0.010
$\hat{r}ij$	63	-0.085	-0.060	0.030	-	0.023	0.006	-0.036	0.068
	67	-0.030	-0.015	-0.050	0.010	-	0.050	-0.018	-0.086
	201	-0.065	-0.070	-0.090	0.010	0.020	-	0.061	-0.159
	242	0.005	0.015	-0.045	0.015	0.000	0.035	-	-0.042

nificant. The reciprocal differences were assumed to be due to the cytoplasmic effect on early growth of the plant which becomes unnoticeable in the later part of the growth.

The general (Table 11) and specific (Table 22) combining ability effects showed that lines 201 and 242 were higher for the general combining ability, and crosses 34 x 63 and 16 x 67 were among the combinations of higher specific combining ability. The lines with high general combining ability had not shown the high specific combining ability.

The heritability of the character seems to be quite high as its broad sense heritability was found to be 81.89%; but the narrow sense heritability was noted to be only 0.074%, indicating a small amount of additive genetic variance responsible for the variability of this character.

12. Growth habit (T12)

The estimates of general and specific combining ability effects show that line 5 with the highest general combining ability favors the erectness and line 201, with the lowest value for general combining ability tends towards the prostrate growth of the plants in various hybrid combinations (Table 11). On the basis of the estimates of specific combining ability effects

(Table 23) the combinations 5 x 63 with highest value could be expected to be erect, whereas cross 16 x 201 may be expected to be medium prostrate.

The heritability estimates in the form of the ratio of additive genetic variance and phenotypic variance (0.093%) and the ratio of total genetic variance and phenotypic variance (88.15%), suggest the highly heritable but less fixable genetic variance responsible for the variation of this character.

13. Plant height at maturity (T13)

Table 24 shows the estimates of general ($\hat{g}i$) and specific ($\hat{s}ij$) combining ability and reciprocal effects ($\hat{r}ij$) for each line and its combinations. It suggests that lines 5, 34 and 67 have the higher and positive values of general combining ability and thus will tend to produce taller plants in various hybrid combinations. The crosses 5 x 63 and 34 x 242 may be stated to be among the best combinations for the plant height as they have the highest positive value of specific combining ability.

Like the variance due to reciprocal differences ($\sigma^2 r$), the estimates of reciprocal differences ($\hat{r}ij$) of the crosses are in general noted to be quite small.

The heritability in broad sense for this character was noted to be quite high (88.08%) but the fixable component of the genetic variance seems to be quite small

Tables 24 and 25:

Estimates of specific combining ability ($\hat{s}ij$), general combining ability ($\hat{g}i$), and reciprocal effects ($\hat{r}ij$) for various genotypes of tetraploids.

Table 24. Height at maturity (T13)

♀ Parents	$\hat{s}ij$ 5	16	34	63	67	201	242	$\hat{g}i$
5	-	1.532	2.096	2.929	-3.941	1.636	-1.681	6.972
16	-0.415	-	-1.425	0.558	0.989	-0.110	0.572	-3.397
34	0.275	2.190	-	1.689	1.421	-0.094	2.698	6.002
$\hat{r}ij$ 63	3.450	0.285	-1.190	-	0.778	-0.345	-0.838	-5.456
67	7.260	-0.425	1.200	2.050	-	0.051	-0.321	4.172
201	-0.450	-3.560	-5.700	1.990	-0.535	-	-1.831	-4.013
242	-0.365	-0.710	-0.125	-0.900	-0.935	-0.250	-	-4.285

Table 25. Per cent of pod set in crosses (T14)

5	-	6.791	8.154	-2.538	-0.058	-2.171	-10.18	-6.298
16	6.320	-	-6.892	10.114	-0.780	-0.493	1.452	5.598
34	-0.465	11.595	-	-2.707	0.427	1.699	-0.682	-7.969
$\hat{r}ij$ 63	6.560	-4.550	-4.690	-	-7.435	-7.423	9.989	2.018
67	-0.045	-7.860	-5.590	-4.285	-	3.311	4.534	-7.066
201	-2.290	-12.39	-4.230	-4.615	-6.700	-	5.076	6.531
242	4.175	-8.660	-1.390	11.160	-14.43	0.340	-	7.183

as its narrow sense heritability was noted to be only 0.700%.

14. Percentage of pod set during crossing (T14)

The analysis of diallel crosses, as mentioned earlier, revealed the significant variance for general and specific combining abilities, and reciprocal difference effects.

The estimates of general combining ability values (Table 11) suggest that lines 242, 201 and 16 were of higher combining ability whereas line 34 was the lowest, followed by lines 67 and 5, for the percent of pod set during the crossing program. On the basis of the estimates of specific combining ability effects (Table 25), combinations 16 x 63, 63 x 242 and 5 x 34 could be expected to have higher percent of pod set in the crossing program. The reciprocal effects for each combination are presented in the above table. The reciprocal differences for each line were also tested by 't' test and it was found that only line 34 had the reciprocal differences in the percentage of pod setting.

The character seems to be highly heritable (broad sense heritability = 80.36%), and has got a high percentage of genetic variance in the form of additive variance, as the narrow sense heritability was found to be 63.79%

Table 26:

Estimates of specific combining ability ($\hat{s}ij$), general combining ability ($\hat{g}i$), and reciprocal effects ($\hat{r}ij$) for various genotypes of tetraploids.

Table 26. Number of seeds per pod set during crossing (T15)

	♀ Parents	$\hat{s}ij$ 5	16	34	63	67	201	242	$\hat{g}i$
	5	-	-0.264	0.533	-0.344	-0.501	-0.908	1.284	0.295
	16	0.025	-	-0.010	-0.257	0.391	0.714	-0.774	0.283
	34	0.325	-0.690	-	0.110	-0.012	-0.534	-0.297	-0.513
$\hat{r}ij$	63	0.530	-0.840	-0.575	-	-0.344	0.114	0.021	-0.081
	67	0.105	0.555	0.095	-0.185	-	0.302	-0.036	-0.349
	201	-0.910	-0.260	-1.205	-0.485	-0.645	-	-0.398	0.302
	242	1.065	-0.285	-1.015	0.005	-0.530	-0.150	-	0.265

Table 27. Heritability estimates of various characters of tetraploids.

	Characters	% Heritability			
		Broad Sense $\sigma^2 G/\sigma^2 p$		Narrow Sense $\sigma^2 A/\sigma^2 p$	
T1	Spring growth (first cut)	72.00	(1.48)	1.39	(0.030)
T2	Fall growth (second cut)	70.79	(1.45)	0.91	(0.020)
T3	Forage yield	79.45	(1.63)	1.52	(0.031)
T4	Seed yield	86.05	(1.77)	8.20	(0.168)
T5	Seeds/pod	75.37	(1.55)	1.23	(0.026)
T6	Dry matter/plant	71.90	(1.48)	0.61	(0.013)
T7	Forage yield (1968)	89.59	(1.84)	2.98	(0.061)
T8	Leaf area	85.21	(1.75)	4.36	(0.090)
T9	Leaf length	86.96	(1.79)	0.31	(0.006)
T10	Frost resistance	84.49	(1.74)	0.09	(0.002)
T11	Plant vigor	81.89	(1.68)	0.07	(0.002)
T12	Growth habit	88.15	(1.81)	0.09	(0.002)
T13	Height at maturity	88.08	(1.81)	0.70	(0.014)
T14	% Pod set	80.36	(1.65)	63.79	(1.320)
T15	No. of seed/pod during crossing	80.84	(1.66)	71.05	(1.460)

Note: Values in the brackets indicate the Genetic gains expected on the respective values of heritability.

$\sigma^2 g$ = genotypic variance, $\sigma^2 p$ = phenotypic variance,

$\sigma^2 A$ = Additive genetic variance (variance due to GCA).

15. <u>Number of seeds per pod set during crossing</u> (T15)

The estimates of general combining ability (Table 11) suggest that the lines 201, 5, 16 and 242 have higher general combining ability and thus could be expected to produce higher numbers of seeds per pod in the crossing program, whereas line 34 will show the minimum number as it has the lowest value of GCA. The specific combining ability effects (Table 26) show that crosses 5 x 242 and 16 x 201 have higher ability to produce more seeds in the crossing program.

The broad sense heritability was found to be 80.84% and its narrow sense value was noted to be 71.05% This implies that the character is quite heritable and most of the genetic variance is present in the form of fixable additive variance.

(b) Hexaploids

The nine quantitative characters noted on the diallel crosses of hexaploid lines were analyzed for their combining ability using Griffing's model I, method 2. They will be dealt with here along with the heritability studies.

The highly significant general combining ability variances were noted for the second cut (X2), forage yield (X3), seed yield (X4) and seeds per pod (X5). The variance for specific combining ability was highly

Table 28. Combining ability analysis of diallel crosses involving hexaploids.

Characters	Mean squares due to		
	GCA ($\sigma^2 g$)	SCA ($\sigma^2 s$)	Residual ($\sigma^2 e$)
D.F.	4	10	42
X1 Spring growth (first cut)	0.0103	0.0092	0.0187
X2 Fall growth (second cut)	0.0283**	0.0185**	0.0064
X3 Total forage yield	0.0770**	0.0442*	0.0307
X4 Seed yield	14.1852**	23.1009**	4.3492
X5 Seeds per pod	0.1459**	0.0925*	0.0604
X6 Dry matter per plant	0.0033	0.0024	0.0063
X7 Plant height	13.0790	95146.3400**	18.2110
D.F.	4	14	-
X8 % of Pod set	504.1720†	357.8440†	-
X9 No. of seeds per pod	14.9210†	1.6170†	-

* Significant at 5% level of probability.

** Significant at 1% level of probability.

† Significance could not be tested.

significant for second cut (X2), seed yield (X4) and plant height (X7); significant for forage yield (X3) and seeds per pod (X5) and not significant for first cut (X1) and dry matter per plant (X6). The percentage of pod set during crossing (X8) and seeds per pod set during crossing (X9) were, though not tested, seemingly significant for general and specific combining ability variances (see Table 28). The heritability estimates of all the characters are presented in Table 31.

1. First cutting (X1)

The estimates of general (Table 29) and specific (Table 30) combining abilities for each line and each cross were made. It seems reasonable to conclude that though the estimates were noted to be rather small, lines 5 and 1 are comparatively superior in their general combining ability and crosses 4 x 5, ~~and~~ 2 x 4, 3 x 5 have higher specific combining ability.

The heritability estimates made on the basis of total genotypic and additive genotypic variances suggest that the contribution of additive genetic effect is about 26.96% of the total phenotypic variance, but the character in general is only 51.04% heritable.

2. Second cutting (X2)

Individual estimates of general and specific com-

Table 29. Estimates of General combining ability effect ($\hat{g}i$) of the hexaploid lines for various characters.

Characters		Parents				
		1	2	3	4	5
X1	Spring growth (first cut)	0.0072	-0.0216	-0.0370	-0.0112	0.0630
X2	Fall growth (second cut)	0.0001	-0.0439	-0.0402	0.0256	0.0024
X3	Total forage	0.0119	-0.0695	-0.0818	-0.0373	0.3200
X4	Seed yield	0.0612	-1.8850	-0.3157	0.0316	2.1000
X5	Seeds/pod	-0.0086	-0.0940	-0.1657	0.0157	0.2500
X6	Dry matter	-0.0243	0.0104	0.0103	-0.0124	0.0290
X7	Height at maturity	1.0480	0.5480	-2.3940	0.2910	0.5050
X8	% Pod set	4.1680	-7.5010	-3.6200	-1.9300	8.4580
X9	Seeds/pod during crossing	0.4350	-0.5300	0.0990	-0.3770	0.3000

bining ability for each line and each cross (Tables 29 and 30) indicate that line 4 shows a higher value for general combining ability and crosses 3 x 5, 1 x 5 and 2 x 5 show comparatively higher values of specific combining ability.

The transmissibility of the character was measured in the form of its broad sense and narrow sense heritabilities, which were found to be 92.31% and 12.91%, respectively. On the basis of this, the character could be considered to be highly heritable, the major part of genetic variance being attributable to dominance and epistatic interaction effects.

3. Forage yield (X3)

The estimates of general combining ability (Table 29) were noted to be higher for line 5, whereas crosses 3 x 5, 2 x 4, 1 x 5 and 2 x 5 showed relatively higher values of specific combining ability (Table 30).

The heritability estimates suggest that the character is highly heritable. Its broad sense heritability was found to be 85.66% and the major part of genetic variance could be attributed to the additive gene action, since its narrow sense heritability was found to reach 50.69%.

Table 30. Estimates of specific combining ability ($\hat{s}ij$) of hexaploid diallel crosses for various characters.

Genotypes	X1	X2	X3	X4	X5	X6	X7	X8	X9
1 x 2	0.008	-0.013	-0.009	-1.125	-0.058	-0.111	0.042	3.46	0.343
1 x 3	-0.024	0.024	-0.006	-0.049	-0.002	-0.029	1.885	-1.07	0.555
1 x 4	-0.021	0.084	0.053	2.963	0.126	0.031	1.900	5.19	0.360
1 x 5	0.049	0.146	0.181	5.992	0.533	0.018	-1.071	-7.62	-0.244
2 x 3	-0.109	-0.200	-0.306	-2.448	-0.141	0.104	-13.814	-2.29	-0.472
2 x 4	0.104	0.115	0.218	1.041	-0.047	0.022	5.700	-5.60	-0.063
2 x 5	0.273	0.133	0.155	3.311	0.325	-0.001	4.385	4.29	0.193
3 x 4	0.007	0.021	0.028	-0.381	0.243	-0.039	-3.057	0.25	0.291
3 x 5	0.138	0.159	0.293	8.250	0.130	0.042	6.128	3.11	0.639
4 x 5	0.104	-0.068	0.036	-1.342	0.001	0.006	0.742	0.08	-0.586

X1 = First cut (kg.), X2 = Second cut (kg.), X3 = Total forage yield 1969 (kg.), X4 = Seed yield per plant (gm.), X5 = Seeds per pod, X6 = Dry matter yield per plant (kg.), X7 = Plant height at maturity (cm.), X8 = Percentage of pod set during crossing, X9 = Number of seeds per pod set during crossing.

4. Seed yield (X4)

On the basis of the estimates of general (Table 29) and specific (Table 30) combining abilities, line 5 may be expected to do better in a number of hybrid combinations and crosses 3 x 5 and 1 x 5 may give the best combination for the seed yield.

The value of heritability considered in its broad sense is 94.71%. At least one third of the genetic variance may be considered to be due to the additive gene effects, since its narrow sense heritability was found to be 34.07%

5. Seeds per pod (X5)

The estimates of general combining ability for each line suggests that line 5 is superior with respect to the character considered, since it has the highest value for general combining ability (Table 29). Table 30 indicates that amongst all combinations, crosses 1 x 5 and 2 x 5 may be expected to have more seeds per pod, since their specific combining ability was higher than that of the rest of the crosses.

The estimates of transmissibility of the character were measured in the form of broad sense and narrow sense heritabilities, which were found to be 86.64% and 48.82%, respectively, i.e., a relatively high portion of genetic variance appears to be of additive genetic

nature. Similar conclusions may also be made from the combining ability analysis.

6. Dry matter yield per plant (X6)

The diallel cross analysis (Table 28) shows that the variances due to general and specific combining ability were not significant, though line 5 could be considered superior for their general combining ability (Table 29). The effect of specific combining ability was also calculated for each cross (Table 30). It can be concluded from the results obtained that cross 2 x 3 might prove to present the best combination for this character.

Although the transmissibility of the character, measured in the form of broad sense heritability, was only 40%, a value of 27.73% for the narrow sense heritability suggests a substantial contribution of additive gene effects.

7. Plant height (X7)

Table 28 (combining ability analysis of diallel crosses) indicates that the variance due to general combining ability is not significant whereas the specific combining ability variance is highly significant and very high. The estimates of general combining ability (Table 29) suggest that line 1 is the one with

the highest general combining ability, and crosses 3 x 5, 2 x 4 and 2 x 5 are amongst the highest combinations for the specific combining ability.

Like the combining ability analysis, the estimates of heritability also show that the major part of the genetic variance for this character is due to allelic and nonallelic interactions. The broad sense heritability (84.38%) was very high in comparison to that of the narrow sense (0.013%).

The data for percent of pod set and number of seeds per pod were recorded as the mean values for each genotype and thus there were no suitable repetitions. The analysis for residual variance was not possible and therefore the significance of various constants could not be tested. The various constants of these characters therefore will be interpreted on the basis of their absolute values.

8. <u>Percentage of pod set during crossing</u> (X8)

The general and specific combining ability variances calculated from the diallel table (Table 28) were found to be quite high and may be assumed to be different from zero.

The estimates of general combining ability (Table 29) for each line suggest that lines 5 and 1 are higher in their ability to set pods in various hybrids. Table 30

Table 31. The heritability estimates for various characters in hexaploids.

Characters	% Heritability			
	Broad Sense σ^2G/σ^2p		Narrow Sense σ^2A/σ^2p	
X1 Spring growth (first cut)	51.04	(1.051)	26.96	(0.555)
X2 Fall growth	92.31	(1.901)	12.91	(0.267)
X3 Forage yield	85.66	(1.764)	50.69	(1.044)
X4 Seed yield	94.71	(1.951)	34.07	(0.701)
X5 Seeds/pod	86.64	(1.784)	48.82	(1.005)
X6 Dry matter	40.00	(0.824)	27.73	(0.571)
X7 Height	84.38	(1.738)	0.013	-

σ^2G = Genotypic variance, σ^2p = phenotypic variance,

σ^2A = Additive genetic variance.

P.S. Values in the brackets designate the expected genetic gain on the basis of respective heritability estimates.

suggests that the crosses 1 x 4, 2 x 5, 1 x 2 and 3 x 5 have comparatively higher specific combining abilities.

9. Number of seeds per crossed pod (X9)

Table 28 suggests that the values of general and specific combining ability variances were quite high and may be assumed to be different from zero.

The estimates of general and specific combining ability (Tables 29 and 30) suggests that the lines 1 and 5 are higher in general combining ability, and the crosses 3 x 5, 1 x 3, 1 x 4, and 1 x 2 are higher in specific combining ability and in number of seeds per crossed pods.

COMPARISON OF GENETIC ESTIMATES OF TETRAPLOIDS AND HEXAPLOIDS FOR THE CHARACTERS UNDER STUDY

1. General and Specific Combining Ability

The general and specific combining ability variances in tetraploids and hexaploids for the characters studied are given in Table 32. The comparison of the values shows that:

(a) the general combining ability variances are, in general, considerably higher in tetraploids. For the characters first cut and dry matter yield, these variances are not significantly different from zero in hexaploids, but are highly significant in the tetraploids. For the character seed yield per plant, the general combining ability in tetraploids in some instances is 12 times as high as in hexaploids. The contrary is true for percent of pod and seed setting during crossing in which the hexaploids show comparatively higher values.

(b) the values of specific combining ability were also higher in tetraploids for most of the characters. Once again, the specific combining ability variances were not significant for first cut and dry matter yield per plant in hexaploids. Like general combining ability, specific combining ability variances for percent of pod and seed setting during crossing were higher in

Table 32. The comparison between the tetraploid and hexaploid combining ability variance for various characters.

Characters	Variances due to GCA ($\sigma^2 g$)		Variances due to SCA ($\sigma^2 s$)	
	Tetraploid D.F. 6	Hexaploid D.F. 4	Tetraploid D.F. 21	Hexaploid D.F. 10
First cut	0.0648**	0.0103	3.9740**	0.0092
Second cut	0.0306**	0.0283**	3.3350**	0.0184**
Total forage yield	0.1560**	0.0770**	14.5900**	0.0442**
Seed yield	178.8500**	14.1852**	1936.8900**	23.1009**
Seeds/pod	0.6030**	0.1459**	48.0860**	0.0925**
Dry matter	0.0049**	0.0033	0.7080**	0.0024
Plant height	416.4890**	13.0790	54534.4500**	95146.3400**
% Pod set	468.4000**	504.1720#	91.5800**	357.8440#
No. of seeds per pod set during crossing	3.9860**	14.9210#	0.5573**	1.6170#

Could not be tested for the significance.

* Significant at 5% level of probability.

** Significant at 1% level of probability.

Table 33. The comparison of the general and specific combining ability effects of the tetraploids and hexaploids.

Characters	$1/G\Sigma\hat{g}i^2$		$1/S\Sigma\hat{s}ij^2$	
	Tetraploids	Hexaploids	Tetraploids	Hexaploids
First cut	0.0045	0.0011	0.0537	0.0056
Second cut	0.0022	0.0010	0.0028	0.0131
Forage yield	0.0066	0.0288	0.1263	0.0289
Seed yield	12.7746	2.0144	19.1267	13.3991
Seeds/pod	0.0431	0.0285	0.3018	0.0507
Dry matter/ plant	0.0004	0.0527	0.0003	0.0029
Plant height	29.6350	1.8674	2.7121	29.8305
% pod set	36.5420	41.2394	31.3531	16.3734
No. of seed set during crossing	0.1200	0.1780	0.2520	0.1715

G = D.F. for general combining ability.

S = D.F. for specific combining ability.

hexaploids than in tetraploids.

Table 33 gives the combining ability estimates in the two populations. Here again, these estimates were higher in tetraploids than in hexaploids except in a few cases. For example, estimates for dry matter were higher for both general and specific combining ability. The second cut and plant height have higher specific combining ability and percent pod set and number of seeds set during crossing have higher general combining ability in hexaploids than in tetraploids.

It is also clear from the above table that the estimates of specific combining ability are in general higher than those of general combining ability in both populations for most of the characters. This may be expected since the lines were earlier selected so that the genes with dominance or epistatic effects may be more important than the genes with additive effects, as the selected lines have a higher degree of similarity of performance than the unselected population.

2. Heritability

The heritability estimates in broad and narrow sense in both populations are given in Table 34. It gives an idea of the magnitude of fixable and non-fixable genetic variances for various characters in both hexaploid and tetraploid populations. It can be

Table 34. Comparison of heritability estimates of tetraploid and hexaploid groups.

Characters	% heritability in Broad sense		% heritability in Narrow sense	
	Tetraploids	Hexaploids	Tetraploids	Hexaploids
First cut	72.00	51.04	3.15	26.96
Second cut	70.79	92.31	1.79	12.91
Forage yield	79.45	85.66	2.09	50.69
Seed yield	86.05	94.71	11.62	34.07
Seeds/pod	75.37	86.64	2.00	48.82
Dry matter	71.90	40.00	1.36	27.73
Plant height	88.08	84.38	0.70	0.01

noted here that the narrow sense heritability for tetraploids is very low as compared to its broad sense value, which indicates that the fixable genetic variances are very small in tetraploids. The narrow sense value for hexaploids, which of course is smaller than the broad sense value, is relatively higher indicating a reasonable amount of fixable genetic variance present in hexaploids. Thus the abundance of dominance and epistatic interactions seems to be the major cause of the expression of most of the characters under study in tetraploids, and the additive action of genes along with various interactions might account for the expression of these characters in the hexaploid population under study.

DISCUSSION OF GENETICAL STUDIES

As mentioned earlier, the general combining ability variance was highly significant (1% level of probability) for all the characters except growth habit (T12), which was significant at the 5% level. The specific combining ability variance was also highly (1% level) significant for all characters but growth habit (T12) which was significant at the 5% level of probability. For seeds per pod set during crossing (T15), the specific combining ability was not significant. Similar results were obtained by Evans et al (1966) for plant width, plant height, longest stem, crown width, vigor, leaf and stem ratio, and leaf hopper yellowing; by Wilcox and Wilsie (1964) for fall growth, forage yield and spring vigor; by Theurer and Elling (1964) for forage yield; by Dudley (1963) for plant height, plant width, spring growth, recovery and leaf hopper yellowing; by Carnahan et al. (1960) for seedling vigor and fall growth habit in the year of establishment. The estimates of the general and specific combining ability also follow a similar trend. In the tetraploid population in general, the SCA variance was larger than the GCA variance. A similar result was also obtained by Evans et al. (1966) for forage yield. This corroborates the results obtained in Maize by Sprague and Tatum (1942) and in alfalfa by Kehr (1961), where

parental lines had been previously selected for general combining ability. These findings suggest that in our tetraploid selected lines, though effects due to both general and specific combining ability were significant, the genetic factors leading to the specific combining abilities were more important for the expression of most of the characters. These results differ from those obtained by Kehr and Gardner (1960), Theurer and Elling (1964), Wilcox and Wilsie (1964) and Evans et al. (1966) where they noted larger GCA variance than SCA variance for various characters studied. For the two characters, namely percentage of pod set during crossing (T14) and seeds per pod set during crossing (T15), the variance of GCA was larger than the SCA variance, which suggests that GCA effects are more important than SCA in controlling the above two characters. Similar results for the unselected characters were also noted by various workers as mentioned earlier.

The importance of nonadditive gene effects in the expression of most of these characters was confirmed by their heritability studies. Here it was noted that, in general, they had the broad sense heritability quite high, ranging from 70.79% for second cut (T2) to 89.59% for vegetative growth in the year of establishment (T7), while the narrow sense heritability (an indication of additive genetic component) was very low. All these

characters had higher SCA variance. This was not true for percentage of pod set during crossing (T14) and number of seeds per pod set (T15) which have narrow sense heritability as high as 63.79% and 71.05%, suggesting the importance of additive gene effects in the expression of these characters. Similar findings for them was also noted in the combining ability studies.

The differences between the reciprocal crosses were found not to be significant for all characters except plant vigor (T11) and percentage of pods set during crossing (T14). In general, the absence of differences between reciprocal crosses in the present study are in agreement with the results of studies by Bolton (1948), Buker and Davis (1961), Davis and Panton (1962), and Davis and Gartner (1966). The reciprocal differences were noted by Bolton (1948) for 3 of 26 clones for seed yield and one parent showing such a difference for forage yield. Similarly, Frakes et al. (1961) made such notations for dry matter, Hanson et al. (1964) for various characters, and Wilcox and Wilsie (1964) for forage yield and fall growth habit. Most of their crosses were made without emasculation, so these differences in general could be attributed to self pollination of clones during seed production. Wilcox and Wilsie (1964) explained their results for forage yield on the basis of cyto-plasmic and genic interactions.

The cases of reciprocal differences for plant vigor (T11) and percentage of pod set during crossing (T14) could be explained on the following grounds: the data of T14 was analyzed also, using 't' test and it was found that it was line 34 which showed significant reciprocal differences for percentage of pod set during crossing. Though the experimental evidences are not available, these differences appear to be due to some cytoplasmic factors.

In hexaploids, the general combining ability variance was found to be highly significant for second cut (X2), total forage yield (X3), seed yield (X4) and seeds per pod (X5) but not significant for first cut (X1), dry matter (X6) and plant height (X7). The specific combining ability variances were highly significant (0.01) for second cut, seed yield and plant height; significant (0.05) for total forage yield and seeds per pod; and non significant for first cut and dry matter yield per plant. Though the variances for percentage of pod set (X8) and number of seeds per pod set during crossing (X9) could not be tested due to unavailability of residual variance, the values for both GCA and SCA are quite high and therefore could be considered as significant. Except for seed yield (X4) and plant height (X7), values of the general combining ability are larger than those for specific combining ability. This suggests that for X4

and X7, the genetic factors responsible for specific combining ability are important, while for other characters, the general combining ability has a greater role in their expression.

The heritability estimates in hexaploids confirm the above findings. Here, though the values for broad sense heritability are higher, the values for narrow sense heritability are also high (except for plant height), and suggest that, in general, additive genetic components are quite important in hexaploids for all the characters except plant height.

It should be pointed out here that to obtain meaningful estimates of genetic variance components from alfalfa crosses, crossing porcedures insuring 100% cross fertilization must be used or the importance of selfing or other maternal effects must be measured in the experiment.

The results of this experiment were obtained from greenhouse and spaced field planted single plants. Several workers, such as Tysdal and Keisselbach (1944), Pearson and Elling (1961) and Theurer and Elling (1964), reported significant genotypic and spacings interactions in alfalfa, and concluded that spaced plantings were of little value in predicting yields from solid seeding. Evans et al. (1966) found positive significant correlation coefficients between GCA effects obtained from various spacings. Their data suggests that progenies could be

evaluated in spaced plantings.

D. RELATIONSHIP BETWEEN THE SELFED AND CROSSED PROGENIES OF THE PARENTAL LINES

(a) Tetraploids

Crossed progenies of each line were tested with respect to variation between the replications as reflected by the performance of the selfs. Table 35 shows the values of correlations obtained between the two progenies for each line and various characters studied.

It is clear from the table that the correlations between the two progenies were quite high for the following characters: first cut, representing the growth in spring, in lines 5, 16, 63, 67 and 242; for second cut, representing growth in fall, in lines 5, 63 and 242; for total forage yield (1969) in 16 and 67; for seed yield in line 16; for seeds per pod in lines 5, 16, 63 and 201; for dry matter per plant in line 34; for leaf area in lines 34 and 63; for leaf length in lines 16, 34, 63 and 242; for frost resistance in line 67; for plant vigor in lines 5, 67 and 242; and for plant height in line 63. Line 242 showed correlation between selfed and crossed progenies for yield in the year of establishment, but none of the lines exhibited any such relation for growth habit.

On the basis of this study, it could be stated that line 16 has the closest association between the performance of its selfed and crossed progenies for most of the

Table 35. Correlation coefficients between the selfed and crossed progenies of various lines for various characters in tetraploids.

Characters	Parental lines						
	5	16	34	63	67	201	242
First cut	0.956*	0.974**	0.139	0.876*	0.981**	0.294	0.869*
Second cut	0.890*	0.702	0.769	0.874*	0.223	0.062	0.934*
Total forage	0.774	0.956*	0.214	0.217	0.930*	0.737	0.648
Seed yield	0.688	0.953*	0.739	0.223	0.301	0.418	0.261
Seeds per pod	0.987**	0.985**	0.278	0.911*	0.436	0.821*	0.801
Dry matter per plant	0.308	0.462	0.942*	0.732	0.085	0.004	0.124
Yield in establishment year	0.001	0.281	0.382	0.799	0.216	0.378	0.831*
Leaf area	0.229	0.501	0.857*	0.915*	0.234	0.199	0.362
Leaf length	0.644	0.898*	0.871*	0.988**	0.602	0.108	0.906*
Frost resistance	0.679	0.203	0.780	0.575	0.972**	0.042	0.800
Plant vigor	0.991**	0.723	0.121	0.029	0.893*	0.181	0.978**
Growth habit	0.521	0.800	0.414	0.199	0.790	0.333	0.522
Plant height	0.486	0.550	0.753	0.916*	0.567	0.105	0.660

* Significant at 5% level of probability.

** Significant at 1% level of probability.

important characters, viz., forage yield, seed yield, first cut, seeds per pod and also for leaf length. Lines 5 and 201 have the higher values (though not significant) for forage and seed yield implying that they might have a close relationship between the performance of their selfed and crossed progenies for these characters. Though the line 63 did not have a high value of correlation between crossed and selfed progenies for seed and forage yield, for most of the other characters it shows a strong correlation between the performance of the above two progenies.

(b) Hexaploids

Like the tetraploids, the correlation coefficient between the performance of selfed and crossed progenies of hexaploid lines was also calculated for all the characters (Table 36).

It is evident from the table that line 5 has a close positive association between the performance of its selfed and crossed progenies for all the characters studied except seeds per pod. Line 4 has significant positive association between the performance of the two progenies for seed yield, seeds per pod and dry matter yield, and lines 2 and 3 show a significant positive correlation for plant height. Line 1 did not show any such association for any of the characters.

Table 36. Correlation coefficients between the selfed and crossed progenies of various lines for various characters in hexaploids.

Characters	Parental lines				
	1	2	3	4	5
First cut	0.408	0.557	0.556	0.145	0.946*
Second cut	0.510	0.407	0.741	0.804	0.843*
Total forage	0.536	0.297	0.199	0.771	0.924*
Seed yield	0.764	0.388	0.314	0.919*	0.913*
Seeds/pod	0.942	0.207	0.355	0.835*	0.395
Dry matter	0.742	0.085	0.244	0.958**	0.955**
Plant height	0.799	0.960**	0.924*	0.305	0.993**

* Significant at 5% level of probability.

** Significant at 1% level of probability.

On this basis it may be predicted that lines 4 and 5 may perform better under conditions where both self and cross pollinations are prevalent, producing selfed and crossed progenies.

As mentioned earlier, alfalfa is an insect cross pollinated crop but self fertilization does occur, especially in areas where the bee population is quite scarce. Under our conditions (Edmonton region) where bee pollination is not very common, self-pollination is the major source of fertilization -- thus a line which has a positive correlation between the performance of its crossed and self progenies may be considered better, especially if the maternally selected plants are used as the variety.

The basis for this relationship between the two progenies could be the genetic background of the line, which in general may be expected to be additive in nature. The selection for the lines of high correlation between the two progenies will probably perform better in our conditions of open pollination where self and cross pollinations are both taking place.

E. ASSOCIATION BETWEEN VARIOUS CHARACTERS

1. Correlations

(a) Tetraploids

As mentioned earlier in relation to the combining ability studies, all the characters had significant values for their variance ratio which suggests that the differences between the genotypes for the characters studied were due to the genetic differences.

The study of the association between the characters was performed by means of correlation analysis. For this purpose, covariances for all possible combinations between the characters were calculated (Table 37). The table shows the values of phenotypic, genotypic and environmental variances and covariances used in the calculation of phenotypic, genotypic and environmental correlations, respectively. The simple correlation coefficient for phenotypic, genotypic and environmental levels are given in Table 38. This table shows that the genotypic correlations have generally higher values than the phenotypic ones and that both correlations agree in sign.

The forage yield seems to show high positive correlation at the phenotypic, genotypic and environmental levels with the first cut, second cut, forage yield in the year of establishment, frost resistance and plant

Table 37 The Error (E), Genotypic (G) and Phenotypic (P) variances and covariances between the thirteen characters of Tetraploids

		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	T_{13}
T_1	P	0.0872												
	G	0.0627												
	E	0.0244												
T_2	P	0.0490	0.0452											
	G	0.0379	0.0320											
	E	0.0070	0.0075											
T_3	P	0.1342	0.0927	0.2239										
	G	0.1029	0.0782	0.1779										
	E	0.0313	0.0145	0.0460										
T_4	P	3.1952	2.3930	5.5415	315.6040									
	G	3.2074	2.3880	5.5455	271.6070									
	E	-0.0127	0.0046	-0.0040	43.9970									
T_5	P	0.0633	0.0315	0.0965	5.1740	0.5425								
	G	0.0693	0.0340	0.1042	4.6870	0.4089								
	E	-0.0060	-0.0026	-0.0077	0.4866	0.1336								
T_6	P	0.0131	0.0069	0.0198	0.8920	0.0288	0.0084							
	G	0.0131	0.0068	0.0209	0.7830	0.0282	0.0061							
	E	-0.0010	0.0000	-0.0011	0.1090	0.0006	0.0024							
T_7	P	0.0726	0.0524	0.1228	2.5164	0.0712	0.0177	0.1278						
	G	0.0712	0.0523	0.1203	2.4760	0.0682	0.0176	0.1145						
	E	0.0014	0.0010	0.0025	0.0404	0.0030	0.0000	0.0133						
T_8	P	0.0226	0.0251	0.0456	1.2297	-0.0903	0.0134	0.0564	0.1434					
	G	0.0218	0.0241	0.0292	1.2330	-0.0960	0.0124	0.0530	0.1221					
	E	0.0005	0.0010	0.0016	-0.0040	0.0056	0.0010	0.0034	0.0212					
T_9	P	-0.0015	0.0111	0.0085	0.5218	-0.0942	-0.0001	0.0102	0.0673	0.0580				
	G	-0.0030	0.0104	0.0063	0.5413	-0.0970	-0.0067	0.0095	0.0579	0.0507				
	E	0.0015	0.0007	0.0022	-0.0194	0.0029	0.0004	0.0007	0.0094	0.0076				
T_{10}	P	0.1039	0.0742	0.1766	6.2970	0.1129	0.0220	0.1089	0.0450	-0.0075	0.2790			
	G	0.0969	0.0739	0.1683	6.0430	0.1133	0.0207	0.1075	0.0386	-0.0120	0.2360			
	E	0.0070	0.0004	0.0083	0.2539	-0.0004	0.0013	0.0014	0.0066	0.0046	0.0430			
T_{11}	P	0.1033	0.0771	0.1773	6.1242	0.0013	0.0229	0.0898	0.0979	0.0390	0.1598	0.2580		
	G	0.0900	0.0055	0.1585	6.0133	0.0091	0.0203	0.0854	0.0921	0.0345	0.0968	0.2110		
	E	0.0133	0.0716	0.0188	0.1109	-0.0078	0.0026	0.0004	0.0058	0.0047	0.0930	0.0460		
T_{12}	P	-0.0354	-0.0267	-0.0623	-0.4926	0.0012	-0.0046	-0.0604	-0.0525	-0.0036	-0.0680	-0.0535	0.1210	
	G	-0.0370	-0.0264	-0.0636	-0.5420	-0.0029	-0.0050	-0.0620	-0.0517	-0.0041	-0.0850	-0.0575	0.1060	
	E	0.0016	-0.0003	0.0014	0.0494	0.0041	0.0004	-0.0021	0.0008	0.0005	0.0002	0.0040	0.0140	
T_{13}	P	-1.0870	-1.1830	-2.2790	-64.4950	1.9016	0.6008	-1.0028	0.8328	0.0331	-3.5359	-2.1272	2.1512	257.9390
	G	-1.0605	-1.1970	-2.2580	-57.8520	2.1271	0.4849	-0.9548	0.7762	0.0106	-3.5058	-3.3230	2.1289	227.1960
	E	-0.0269	0.0146	-0.0205	-6.6430	-0.2255	0.1159	-0.0480	0.0566	0.0225	-0.0301	0.1958	0.0223	30.7430

T_1 = First cut, T_2 = Second cut, T_3 = Total forage (1969), T_4 = Seed yield (1969), T_5 = Seed per pod, T_6 = Dry matter per plant,

T_7 = Forage yield (1968 - year of establishment), T_8 = Leaf area, T_9 = Leaf length, T_{10} = Frost resistance, T_{11} = Plant vigor,

T_{12} = Growth habit, T_{13} = Plant height at maturity.

Table 30 The Simple (r) Genotypic ($_rg$) and Phenotypic ($_rph$) Correlation Coefficients between the thirteen characters of Tetraploids

		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
T_2	r	0.5306											
	r_g	0.7790											
	r_{ph}	0.7810											
T_3	r	0.9330	0.7817										
	r_g	0.9730	0.9550										
	r_{ph}	0.9600	0.9217										
T_4	r	-0.0122	0.0080	-0.0052									
	r_g	0.7767	0.7465	0.9944									
	r_{ph}	0.6090	0.6337	0.8725									
T_5	r	-0.1050	-0.0840	-0.0982	0.2000								
	r_g	0.4338	0.2749	0.3862	0.3800								
	r_{ph}	0.2910	0.2010	0.2768	0.3950								
T_6	r	-0.1348	0.0003	-0.1099	0.3396	0.0346							
	r_g	0.6733	0.4548	0.5720	0.6086	0.5648							
	r_{ph}	0.4829	0.3440	0.4563	0.4560	0.4249							
T_7	r	0.0810	0.0237	0.1610	0.0528	0.0711	0.0011						
	r_g	0.8395	0.2418	0.8431	0.4439	0.3151	0.6706						
	r_{ph}	0.6881	0.1991	0.7262	0.3946	0.2709	0.5402						
T_8	r	0.0207	0.0793	0.0525	-0.0040	0.1065	0.1432	0.2025					
	r_g	0.2496	0.3560	0.1981	0.2142	-0.4297	0.4543	0.4499					
	r_{ph}	0.2021	0.3126	0.2545	0.1828	-0.3246	0.3862	0.4167					
T_9	r	0.0346	0.0993	0.1192	-0.0336	0.0916	0.1021	0.0686	0.5987				
	r_g	-0.0537	0.2376	0.0664	0.1459	-0.6748	-0.0381	0.1246	0.7358				
	r_{ph}	-0.0216	0.2170	0.0747	0.1216	-0.5299	-0.0103	0.1180	0.7363				
T_{10}	r	0.2150	0.0199	0.1850	0.1830	0.0056	0.1280	0.0600	0.2178	0.2535			
	r_g	0.7959	0.6600	0.8210	0.7548	0.3650	0.5460	0.6539	0.2270	-0.1100			
	r_{ph}	0.6657	0.7834	0.7060	0.6707	0.2900	0.4520	0.5764	0.2259	-0.0587			
T_{11}	r	0.1246	0.2954	0.1280	0.0773	-0.0987	0.2234	0.0170	0.3078	0.2490	1.3600		
	r_g	0.7812	0.8022	0.8175	0.7937	0.0309	0.5654	0.5490	0.8898	0.3317	0.4325		
	r_{ph}	0.6887	0.7139	0.7376	0.6786	0.0034	0.4890	0.4945	0.7982	0.3196	0.6446		
T_{12}	r	0.0850	-0.0270	0.0526	0.0620	0.0926	0.0719	-0.0137	0.0470	0.0454	0.0650	0.1550	
	r_g	-0.4240	-0.3910	-0.3475	-0.0946	-0.0130	-0.1970	-0.5665	-0.4530	-0.0560	-0.5370	-0.3830	
	r_{ph}	-0.3450	-0.6010	-0.3789	-0.0790	0.0045	-0.1430	-0.4860	-0.3990	-0.0430	-0.3740	-0.3030	
T_{13}	r	-0.0310	0.0300	-0.0172	-0.1800	-0.1110	0.4280	-0.0750	0.0700	0.0460	-0.0080	0.1630	0.0339
	r_g	-0.2800	-0.4090	-0.3550	-0.2320	0.2200	0.4120	-0.1870	0.1470	0.0030	-0.4780	-0.4790	0.4335
	r_{ph}	-0.2290	-0.3460	-0.2998	-0.2260	0.1600	0.4060	-0.1740	0.1360	0.0080	-0.4160	-0.2600	0.3855

r - Significant at 0.159*

$_rg$ and $_rph$ - Significant at 0.273*

T_1 = First cut, T_2 = Second cut, T_3 = Total Forage (1969), T_4 = Seed yield (1969), T_5 = Seeds per pod, T_6 = Dry matter per plant,

T_7 = Forage yield (1968 - year of establishment), T_8 = Leaf area, T_9 = Leaf length, T_{10} = Frost resistance, T_{11} = Plant vigor,

T_{12} = Growth habit, T_{13} = Height of plants at maturity.

vigor. The leaf area and its length seem to be uncorrelated with the total vegetative production. The simple correlation between forage yield and growth habit was not significant, but the negative values for genotypic and phenotypic correlations tend to imply that the erectness of plants may be positively associated with forage production.

The seed yield has positive association with seeds per pod, dry matter yield per plant and frost resistance at all three levels, viz., genotypic, phenotypic and environmental. Though the values of simple correlations are non significant between seed yield and first cut, second cut, forage yield in the year of establishment, forage yield 1969 and plant vigor; the significant correlations at genotypic and phenotypic levels implies their association genotypically and phenotypically. Spreading habit and leaf characters seem to have no bearing on seed production. Though the observed values are not very high, excessive plant height might have a negative effect on seed yield.

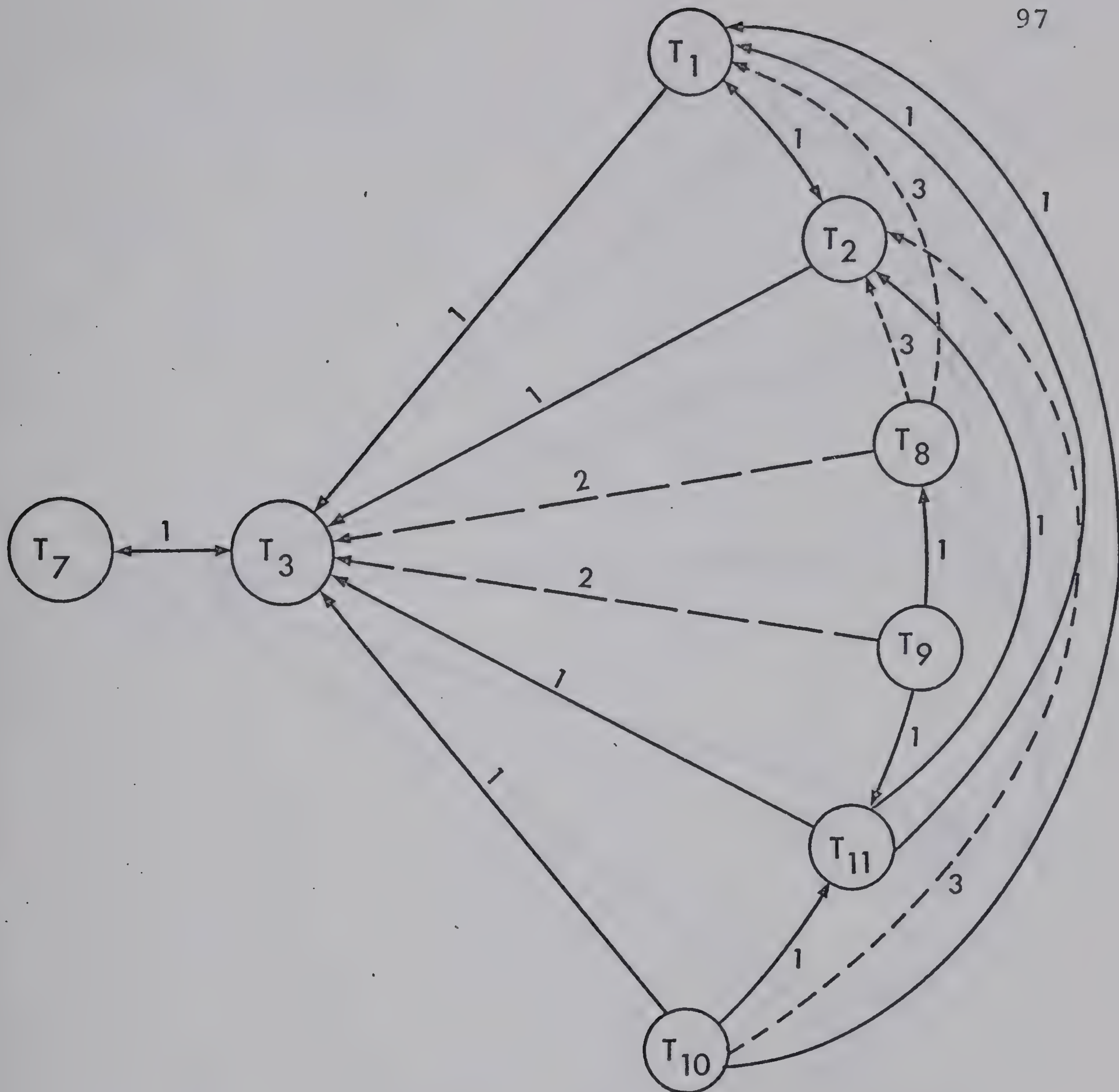
Among the other combinations, significant correlations were found between leaf area and the characters leaf length, frost resistance and plant vigor; between frost resistance and plant vigor with first cut and second cut, which are also associated. A positive relationship between height and plant vigor, and plant

vigor and growth habit could be seen, though their genotypic and phenotypic values show a negative trend between the two characters. Similarly, taller plants seem to have more percentage of dry matter yield, but height was not found to have association with seed yield.

The rest of the combinations in general show no association at the environmental level, but exhibit a significant value of positive or negative correlation coefficients at genotypic and/or phenotypic levels.

Figures 1 and 2 show the relative importance of various characters and their relationship with forage and seed yields, respectively, which also indicates the path of the causal relationship. On this basis it could be stated that the main contributors for forage yield are: first cut, representing the growth in spring, second cut, representing the fall growth, plant vigor and frost resistance. The yield in the year of establishment (1968) was found to be associated with the forage yield in 1969. Other characters are shown to contribute indirectly to the effect. Similarly, seed yield seems to have direct dependence on the causes Seeds per pod, dry matter yield and frost resistance. Plant height seems to have a negative association with seed yield.

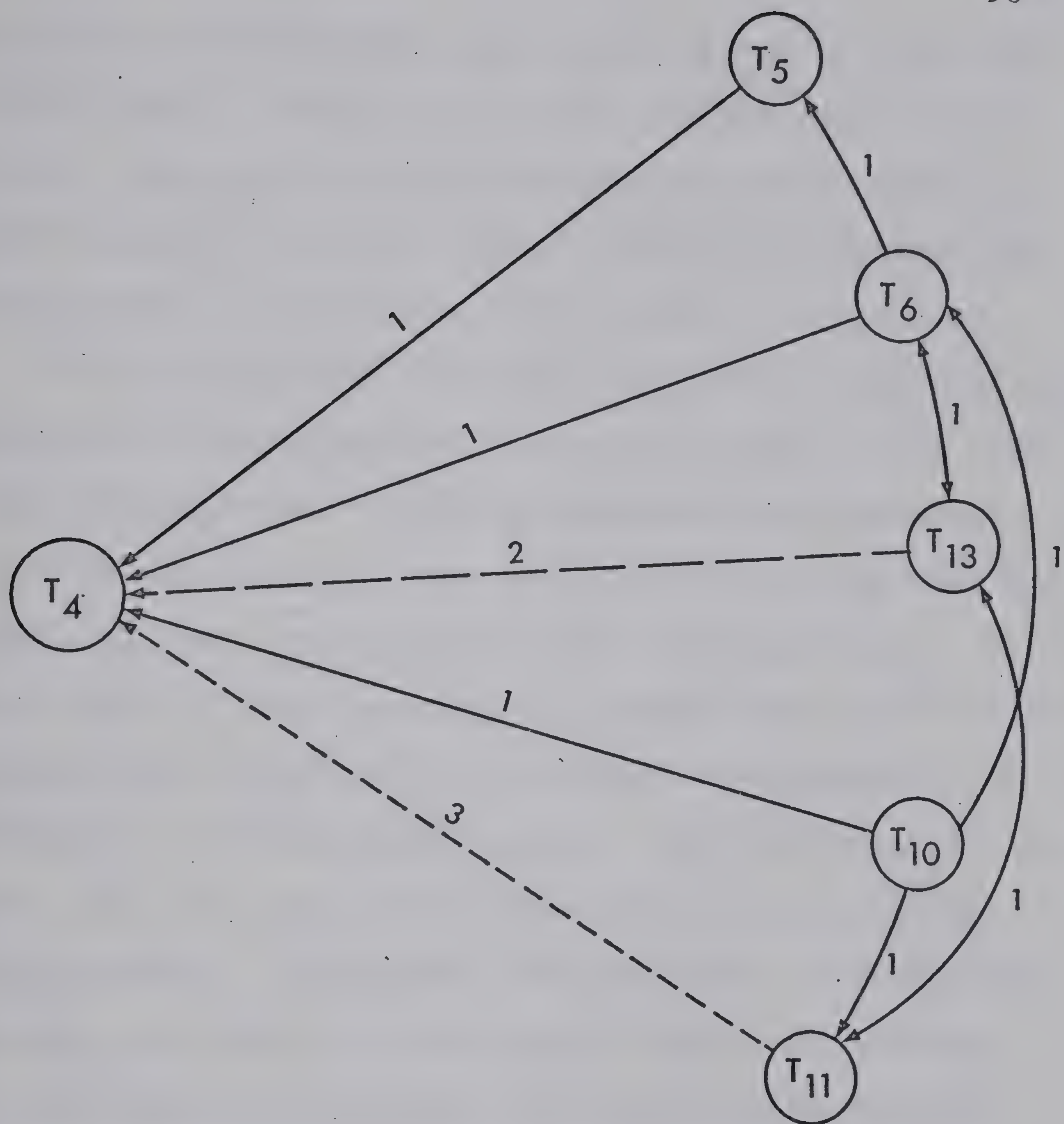
The partial correlation was calculated for the



1. Significant at all three (environmental, genotypic and phenotypic) levels.
2. Significant at only one level.
3. Significant at two levels

Fig. 1. Showing the relationship between the forage yield (1969) and its related characters in tetraploids.

T_1 = First cut, T_2 = Second cut, T_3 = Total forage (1969), T_7 = Forage yield in the establishment year (1968), T_8 = Leaf area, T_9 = Leaf length, T_{10} = Frost resistance, T_{11} = Plant vigor.



P.S. 1. Significant at all three (environmental, genotypic and phenotypic) levels.
2. Significant at only one level.
3. Significant at two levels.

Fig. 2. Showing the relationship between the seed yield and its related characters in tetraploids.

T_4 = Seed yield, T_5 = Seeds per pod, T_6 = Dry matter per plant, T_{10} = Frost resistance, T_{11} = Plant vigor, T_{13} = Plant height at maturity.

directly correlated character combinations of seed and forage yield. Table 39 shows the partial correlations between seed yield and its related characters when a third character is kept constant with their respective environmental, genotypic and phenotypic correlations.

It is clear from the table that at the environmental correlation level, partial correlations are of the same sign and magnitude. When the genotypic and phenotypic correlations are used, the partial correlations have the same sign, but not necessarily the same magnitude. From this table it seems possible to predict that correlations between seed yield and seeds per pod are generally unaffected by the dry matter content and the height of the plant, but are affected when the frost resistance is kept constant. It is also clear that the relationship between seed yield and dry matter content is affected by frost resistance, height of plant at maturity and probably seeds per pod. A genotypic and phenotypic partial association between seed yield and frost resistance is affected when plant height, dry matter content and seeds per pod are constant and at environmental level they show no effect on such association. The partial correlation between seed yield and plant height follows the findings for the association between the seed yield and frost resistance. In general, genotypic and phenotypic partial correlations were found to be

higher than the environmental partial correlations.

Table 39. The partial correlations involving seed yield and its related characters in the tetraploids.

Characters	Simple Correlations	Partial correlations			
		Constants			
		T5	T6	T10	T13
T4 vs. T5	$r = 0.200$	-	0.211	0.197	0.241
T4 vs. T5	$r^g = 0.380$	-	0.214	0.104	0.870
T4 vs. T5	$r^{ph} = 0.395$	-	0.309	0.252	0.756
T4 vs. T6	$r = 0.339$	0.345	-	0.338	0.385
T4 vs. T6	$r^g = 0.609$	0.546	-	0.434	1.220
T4 vs. T6	$r^{ph} = 0.456$	0.388	-	0.434	0.271
T4 vs. T10	$r = 0.034$	0.034	-0.010	-	0.069
T4 vs. T10	$r^g = 0.565$	0.495	0.350	-	1.160
T4 vs. T10	$r^{ph} = 0.425$	0.301	0.401	-	1.042
T4 vs. T13	$r = 0.183$	0.186	0.150	0.192	-
T4 vs. T13	$r^g = 0.755$	0.716	0.636	1.104	-
T4 vs. T13	$r^{ph} = 0.670$	0.849	0.596	1.029	-

T4 = seed yield, T5 = seeds per pod, T6 = dry matter per plant, T10 = frost resistance, T13 = plant height.

Partial 'r' > 0.275 - significant at 5%.

Partial 'r' > 0.355 - significant at 1%.

The partial correlations of forage yield with first cut, representing the growth in spring, and second cut, representing the growth in fall, were found to be quite high, like their simple correlations, when other related characters, i.e., fall or spring growth, leaf area, leaf length and spreading of the plants, are kept constant. The partial correlation between total forage yield and spreading was not significant when various factors were held constant, as is clear from Table 40.

Table 40. The partial correlations involving forage yield and its related characters in the tetraploids.

Characters	Simple Correlations	Partial correlations				
		Constants				
		T1	T2	T8	T9	T12
T3 vs. T1	0.930	-	0.974	0.931	0.953	0.930
T3 vs. T2	0.780	0.921	-	0.779	0.778	0.783
T3 vs. T12	0.050	-0.067	0.114	0.048	0.045	-

T1 = first cut, T2 = second cut, T3 = total forage, T8 = leaf area, T9 = leaf length, T12 = Growth habit.

Partial 'r' > 0.275 - significant at 5%.

Partial 'r' > 0.355 - significant at 1%.

(b) Hexaploids

As mentioned earlier, the analysis of variance was performed for all the characters considered and the significant ratios (Table 3) suggest the genotypic differences between the genotypes.

The obtained phenotypic, genotypic and environmental variances and covariances, associated with various characters and their combinations, are given in Table 41.

The phenotypic, genotypic and environmental correlations were calculated for all possible combinations of these characters. They are given in Table 42. It is evident from the above table that forage yield taken as total vegetative production in the season is positively associated at all three levels (genotypic, phenotypic and environmental), with first cut representing growth in spring, and second cut representing growth in fall. Similarly, seed yield is correlated with seeds per pod.

In general, environmental correlation values were very low as compared to the values of genotypic and phenotypic correlations. The genotypic values are higher than the phenotypic values, but have the same sign. This tends to imply that genetically most of the combinations presented in Table 42 are highly correlated, which they do not show in this environment. All these combinations show a positive trend of their association.

Table 41. The phenotypic (P), genotypic (G) and environment (E) variances and covariances between the seven quantitative characters of hexaploids.

		X1	X2	X3	X4	X5	X6	X7
	P	0.0382						
X1	G	0.0195						
	E	0.0187						
	P	0.0464	0.8330					
X2	G	0.0434	0.0769					
	E	0.0029	0.0064					
	P	0.0844	0.1296	0.2142				
X3	G	0.0634	0.1203	0.1835				
	E	0.0210	0.0093	0.0307				
	P	1.3182	2.2832	3.5757	81.2181			
X4	G	1.3020	2.2761	3.5496	77.8689			
	E	0.0162	0.0171	0.0261	4.3492			
	P	0.0967	0.1678	0.2651	4.9405	0.4524		
X5	G	0.0966	0.1660	0.2688	4.7863	0.3920		
	E	0.0001	0.0002	-0.0037	0.1642	0.0604		
	P	0.0038	0.0046	0.0084	0.3019	0.0146	0.0105	
X6	G	0.0019	0.0037	0.0057	0.2973	0.0079	0.0042	
	E	0.0019	0.0010	0.0027	0.0146	0.0007	0.0063	
	P	1.3670	2.0040	3.3437	43.8570	2.6940	-0.3699	116.6090
X7	G	1.4150	1.9420	3.3465	41.3490	2.4200	-0.4459	110.2060
	E	-0.0480	0.0624	-0.0028	2.5080	0.2740	0.7610	18.2110

X1 = First cut, X2 = Second cut, X3 = Forage yield (1969), X4 = Seed yield, X5 = Seeds per pod, X6 = Dry matter per plant, X7 = Plant height.

Table 42. The environmental (r), genotypic (r^g) and phenotypic (r^{ph}) correlations between various pairs of characters in hexaploids.

		X1	X2	X3	X4	X5	X6
X2	r	0.267					
	r^g	1.120					
	r^{ph}	0.821					
X3	r	0.876	0.551				
	r^g	1.050	1.010				
	r^{ph}	0.933	0.970				
X4	r	0.056	0.102	0.071			
	r^g	1.040	0.918	0.927			
	r^{ph}	0.729	0.862	0.852			
X5	r	0.003	0.091	-0.085	0.320		
	r^g	0.415	0.956	1.085	0.855		
	r^{ph}	0.735	0.967	0.851	0.810		
X6	r	0.175	0.149	0.194	0.088	0.039	
	r^g	0.235	0.205	0.206	0.513	0.194	
	r^{ph}	0.314	0.157	0.177	0.321	0.210	
X7	r	0.082	0.183	0.004	0.282	0.262	0.2247
	r^g	1.021	0.706	0.785	0.472	0.389	-0.6937
	r^{ph}	0.647	0.643	0.669	0.448	0.371	0.3343

X1 = First cut, X2 = Second cut, X3 = Forage yield (1969), X4 = Seed yield, X5 = Seeds per pod, X6 = Dry matter per plant, X7 = Plant height.

Figures 3 and 4 show the relationship between the characters studied.

The partial correlations calculated between the two characters when the third one is kept constant, are presented in Table 43 with their corresponding values of simple correlations. It is evident here that, except the cases dealt with below, partial correlations show the same trend as their simple correlations. The partial correlations at genotypic and phenotypic levels were not significant between first cut and seed yield when the second cut was kept constant. Similarly, partial correlation between second cut and seed yield, when total forage and seeds per pod were kept constant, were not significant at both the genotypic and phenotypic levels. The genetic partial correlation between second cut and number of seeds per pod with total forage kept constant was found to be significant, but with a sign different from that of the simple correlations. In general, simple correlations and partial correlations between second cut and dry matter yield were not significant, but the partial correlation (genotypic) moved up to a level of significance when the seed yield was constant. Change in sign was also noted for the following combinations: at genotypic level between forage and seed yield when first cut was constant, at phenotypic level between forage yield and seeds per pod when second cut was

Fig. 3

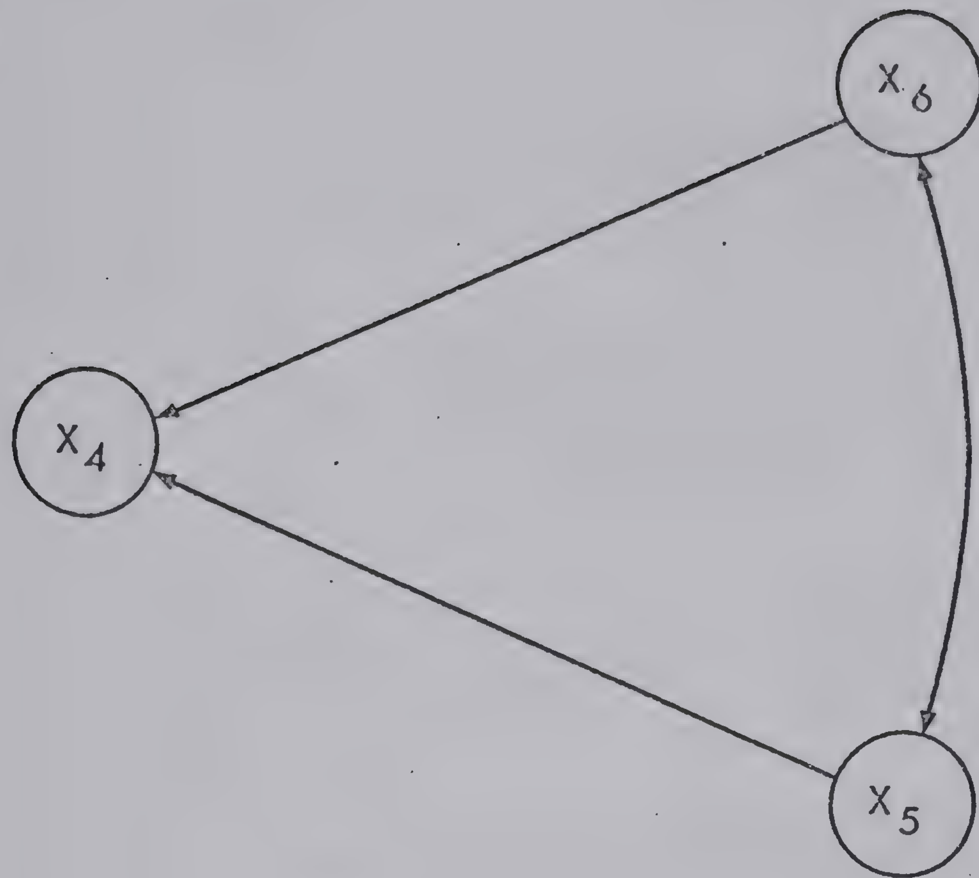


Fig. 4

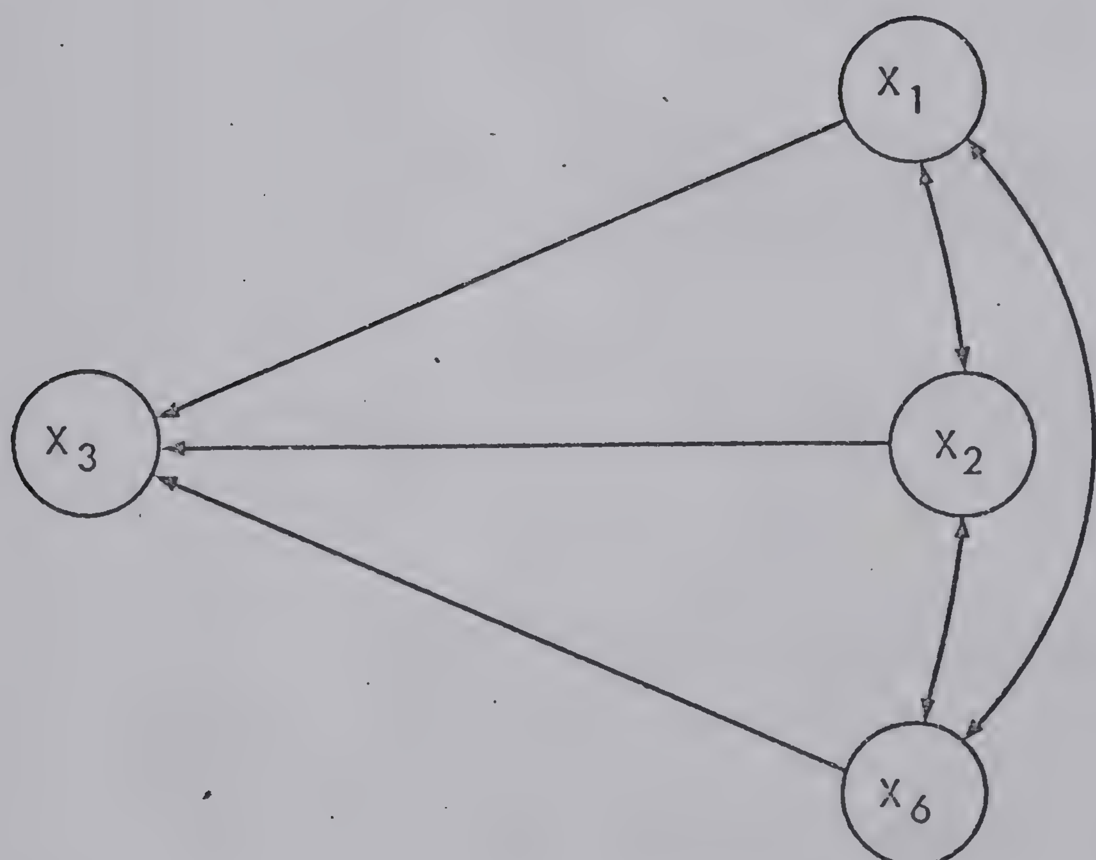


Fig. 3. Relationship between the seed yield and its related characters in hexaploids.

Fig. 4. Relationship between the forage yield and its related characters in hexaploids.

X_1 = First cut, X_2 = Second cut, X_3 = Forage yield (1969), X_4 = Seed yield, X_5 = Seeds per pod, X_6 = Dry matter per plant.

Table 43. Partial correlations between the pairs of characters in Hexaploids.

Characters	Simple Correlations	Partial Correlations					
		Constants					
		X1	X2	X3	X4	X5	X6
X1 vs. X2	$r = 0.267$	-	-	0.536	0.263	0.268	0.248
X1 vs. X2	$r^g = 1.120$	-	-	1.311	1.459	1.710	1.127
X1 vs. X2	$r^{ph} = 0.821$	-	-	0.960	0.555	0.638	0.823
X1 vs. X3	$r = 0.876$	-	1.014	-	0.876	0.879	0.872
X1 vs. X3	$r^g = 1.050$	-	-1.136	-	0.802	1.566	1.053
X1 vs. X3	$r^{ph} = 0.933$	-	0.984	-	0.870	0.864	0.939
X1 vs. X4	$r = 0.056$	-	0.030	-0.070	-	0.058	0.041
X1 vs. X4	$r^g = 1.040$	-	0.059	0.555	-	1.452	1.102
X1 vs. X4	$r^{ph} = 0.729$	-	0.074	-0.350	-	0.255	0.699
X1 vs. X5	$r = 0.003$	-	-0.022	0.161	-0.016	-	-0.004
X1 vs. X5	$r^g = 0.415$	-	-1.432	-1.374	-1.201	-	0.388
X1 vs. X5	$r^{ph} = 0.735$	-	-0.405	-0.312	0.288	-	0.721
X1 vs. X6	$r = 0.175$	-	0.142	0.093	0.171	0.175	-
X1 vs. X6	$r^g = 0.235$	-	0.011	0.063	-1.216	0.173	-
X1 vs. X6	$r^{ph} = 0.314$	-	0.328	0.420	0.123	0.241	-
X2 vs. X3	$r = 0.551$	0.682	-	-	0.548	0.563	0.538
X2 vs. X3	$r^g = 1.010$	-1.028	-	-	1.069	-0.221	1.011
X2 vs. X3	$r^{ph} = 0.970$	0.992	-	-	0.888	1.099	0.969
X2 vs. X4	$r = 0.102$	0.091	-	0.883	-	0.077	0.090
X2 vs. X4	$r^g = 0.908$	-1.713	-	-0.344	-	0.661	0.968
X2 vs. X4	$r^{ph} = 0.862$	0.674	-	0.279	-	0.091	0.868

Table 43 (cont'd)

Characters	Simple Correlations	Partial Correlations					
		Constants					
		X1	X2	X3	X4	X5	X6
X2 vs. X5	$r = 0.091$	0.183	-	0.166	0.062	-	0.086
X2 vs. X5	$r^g = 0.956$	1.070	-	-1.343	0.832	-	0.954
X2 vs. X5	$r^{ph} = 0.967$	0.939	-	1.109	0.866	-	0.967
X2 vs. X6	$r = 0.149$	0.108	-	0.052	0.141	0.146	-
X2 vs. X6	$r^g = 0.205$	-0.119	-	-0.022	-0.781	0.068	-
X2 vs. X6	$r^{ph} = 0.157$	-0.186	-	-0.061	-0.246	-0.185	-
X3 vs. X4	$r = 0.071$	0.046	0.018	-	-	0.104	0.055
X3 vs. X4	$r^g = 0.927$	-1.804	-0.003	-	-	-0.003	0.978
X3 vs. X4	$r^{ph} = 0.852$	0.698	0.129	-	-	0.414	0.853
X3 vs. X5	$r = -0.085$	-0.085	-0.163	-	0.114	-	-0.095
X3 vs. X5	$r^g = 1.085$	1.229	1.083	-	1.503	-	1.089
X3 vs. X5	$r^{ph} = 0.851$	0.640	-1.405	-	0.407	-	0.864
X3 vs. X6	$r = 0.194$	0.086	0.136	-	0.189	0.198	-
X3 vs. X6	$r^g = 0.207$	-0.131	-0.008	-	-0.837	-0.011	-
X3 vs. X6	$r^{ph} = 0.177$	-0.339	0.103	-	-0.195	-0.003	-
X4 vs. X5	$r = 0.320$	0.320	0.314	0.328	-	-	0.318
X4 vs. X5	$r^g = 0.855$	1.629	-0.194	-0.955	-	-	0.897
X4 vs. X5	$r^{ph} = 0.880$	0.742	0.360	0.564	-	-	0.878

Partial 'r' $>$ 0.590 - significant at 5%.

Partial 'r' $>$ 0.694 - significant at 1%.

See page 104 for the explanation of X1, X2.....X6.

constant, at genotypic level between forage and dry matter yield when seed yield was constant, and between seed yield and seeds per pod when forage yield was kept constant. Some of the partial correlations were not significant, although their simple correlations were significant. They may be listed as below, phenotypic and genotypic partial correlations between first cut and seed yield when second cut was constant and between forage yield and seed yield when second cut was constant. Similar results were also obtained at the phenotypic level between second cut and seed yield when seeds per pod was kept constant. The other combinations showed almost the same trend as their simple correlations of phenotypic, genotypic and environmental levels.

DISCUSSION

As is well known, correlated variation of two characters may be due to similar actions on both characters by genes or chromosomes, on the one hand, or by environmental influence on the other. If genetic correlation is high, it is sometimes useful to increase character A by selecting for B. Favorable circumstances are high heritability and ease of selection for B and high genetic correlation between it and A. It may be that, although the phenotypic correlation between the two characters is zero, by partitioning the genetic and environmental portions are found to be opposite in sign. Apart from the biological interest in such situations, the use of environmental correlations to correct for environmental variations and of genotypic correlations to aid selection, might be profitable. The phenotypic correlations published frequently can seldom be interpreted in terms of genetic and environmental effects.

Dudley and Hanson (1961) observed that in their studies of interrelations among characters, the genotypic and phenotypic coefficients were similar in sign and magnitude. In this experiment, most of the combinations showed similar results in both the tetraploid and hexaploid populations. This could mean that environmental sources of variation had little influence on the expres-

sion of these associations. In some cases, genetic correlation value was higher than that of phenotypic and environmental values, which may be attributed to the environmental effect dropping the value of phenotypic associations.

For instance, in this case, seed yield was found to be associated at all the levels, i.e., environmental, genotypic and phenotypic, with seeds set per pod, dry matter yield per plant, and frost resistance. This association could be explained on the grounds that seed per pod directly affects the number of seeds per plant, dry matter gives an idea about the size of plant (area for the pod set), and frost resistance protects the plant from damage, especially during flowering. Similar results were also obtained by Nielsen and Mortensen (1963) for seed yield and seed set, seed yield and hay yield at maturity; by Liang and Riedl (1964) for plant height, number of stems and fertility with seed yield; and by Miller and Schonhort (1968) for seed yield with pod and seed set and seed yield with self fertility.

The forage yield was found to be associated with growth in spring, growth in fall, forage yield in the establishment year, frost resistance and plant vigor, at all the environmental, genotypic and phenotypic levels. This seems quite obvious as all of these characters have, in one way or another, direct impact on the total vegeta-

tive production. Similar results were also obtained by Tysdal and Kiesselbach (1944) for yield with height and upright plants; by Burton (1957) for yield and number of stems; by Dudley and Hanson (1961) for yield with spring growth, recovery and height; by Nielsen and Mortensen (1963) for height with vigor; by Liang and Riedl (1964) for forage with plant height, number of leaves, number of nodes and number of stems; by Davis and Panton (1962) for forage yield with vigor, height, crown width and seedling height; and by Wilcox and Wilsie (1964) for yield, less erectness and spring vigor. Some other combinations which showed the association within themselves are quite clear (Table 38). Some of them are also suggested by the experimental evidences reported earlier. evidences reported earlier.

Similar results were also obtained for the hexaploid population.

The results of partial correlations in tetraploids followed the trend of simple correlations. The same was true for hexaploids, barring certain exceptions which are self explanatory.

2. Selection Indices

The method of discriminant function was used to construct the selection indices involving various characters directly associated with the seed and forage yield. They will be dealt with here separately for tetraploids and hexaploids.

A. Tetraploids

(a) Selection indices involving seed yield

Table 44 shows the indices, their discriminant function and the genetic advance obtainable for these combinations. The greater genetic advance in selection for seed yield could possibly be obtained when the selection is based on seed yield along with seeds per pod and dry matter yield per plant, as the genetic advances for seed yield and seeds per pod, seed yield and dry matter yield, and seed yield, seeds per pod and dry matter yield were found to be 138.95, 138.937, and 138.645, respectively. The character frost resistance does not seem to increase the genetic gain when it is included in the selection program, as the value of genetic advance has gone down whenever it was taken as the basis of selection along with other characters.

(b) Selection indices involving forage yield

Seven indices were constructed and are given in

Table 44. Discriminant function and expected genetic advance in seed yield from the use of different selection indices in tetraploids.

Selection indices	Discriminant function	Genetic gain
T4, T5	y=16.7334T4 + 12.3340T5	138.95 (100)*
T4, T6	y=16.7445T4 + 51.4877T6	138.92 (99.99)
T4, T10	y=15.3291T4 + 85.8856T10	133.24 (96.37)
T4, T5, T6	y=16.6598T4 + 11.3535T5 + 32.0699T6	138.64 (99.77)
T4, T5, T10	y=15.2044T4 + 10.7748T5 + 85.5809T10	132.77 (95.55)
T4, T6, T10	y=15.3413T4 - 5.0762T6 + 86.0083T10	133.29 (95.92)
T4, T5, T6, T10	y=13.6929T4 + 14.5161T5 + 831.3423T6 + 64.4054T10	136.06 (97.92)

where T4 = seed yield, T5 = seeds per pod, T6 = dry matter per plant and T10 = frost resistance.

*Values in brackets indicate relative efficiency of selection.

Table 45. Selection indices involving forage yield in tetraploids.

Selection indices	Discriminant function	Genetic gain	
T1, T2	y=2.3093T1 - 0.8191T2	0.7090	-
T1, T3	y=0.9353T1 + 1.8339T3	1.2780	(100)*
T1, T10	y=2.4691T1 + 6.2579T10	2.6313	(205.8)
T1, T11	y=2.1214T1 + 5.7194T11	2.3844	(186.5)
T1, T2, T3	y=-2.6986T1 + 4.0958T2 + 5.6942T3	2.0339	(159.1)
T1, T2, T3, T10	y=-52.8238T1+53.4490T2 +56.9859T3+6.7382T10	3.5551	(278.1)
T1,T2, T3, T10, T11	y=3974.1519T1+3942.1093T2 - 3867.8116T3 -36.0131T10+40.1481T11	3.7630	(294.4)

Where T1 = first cut, T2 = second cut, T3 = total forage, T10 = frost resistance and T11 = plant vigor.

* Values in brackets indicate relative efficiency of selection.

Table 46. Discriminant function and expected genetic advance from the use of different selection indices in hexaploids.

Selection indices	Discriminant function	Genetic gain
Seed yield		
X4, X5	y=6.1704X4 + 5.4043X5	10.8465
X4, X6	y=6.3897X4 + 1.0486X6	10.8625
X4, X5, X6	y=5.9957X4 + 5.3415X5 + 2.3603X6	10.9279
forage yield		
X1, X2	y=1.8108X1 - 2.1879X2	0.3414
X1, X3	y=0.7994X1 + 0.5783X3	0.3390
X1, X6	y=0.8387X1 - 0.0680X6	0.2459
X1, X2, X3	y=0.9414X1 - 2.4301X2 + 2.1209X3	0.5038
X1, X4	y=21.6119X1 + 5.2771X4	1.4414
X1, X4, X6	y=22.6530X1 + 5.1841X4 + 13.1924X6	1.5034

Where X1 = first cut, X2 = second cut, X3 = total forage, X4 = seed yield, X5 = seeds per pod, X6 = dry matter.

Table 45. It seems probable here that the inclusion of all the characters considered in this study will be helpful in a selection program for increasing the forage yield. Considering the genetic advance obtained on the basis of first cut and total forage yield, the other combinations showed in general the increased relative efficiency of selection. As high as 294.4% of relative efficiency of selection (G.A. = 3.763) was observed for the combination which included first cut, second cut, frost resistance, plant vigor and total forage yield. Other combinations showed the relatively higher values of genetic gain.

B. Hexaploids

The indices involving various combinations along with seed and forage yields are presented in Table 46. It suggests that for seed yield, maximum genetic advance may be obtained by selecting on the basis of seeds per pod, dry matter yield and, of course, seed yield. The combinations involving forage yield suggest the maximum gain through the first and second cuttings. Two other combinations calculated, including forage yield and seed yield, showed that the selection based on the dry matter yield increases the relative efficiency of selection as its genetic advance was noted to be relatively high in comparison to the other combinations.

DISCUSSION

Correlations between selection of multiple objectives or between component characters related to economic objects are important in index construction. The problem of efficient selection indices was first studied by Smith (1936) using discriminant function and later by Hazel (1943) using Wright's path coefficients. In general the optimum weight assigned to an index component is larger as:

(i) its direct economic value is high,

(ii) its heritability is high,

(iii) its genetic correlations with other economically important components of low heritability are high, and

(iv) its environmental correlations with other economically important components are low or negative.

In general, it was found that in tetraploids, the selection index comprising the direct components of seed yield did not show any appreciable improvement over straight selection based on the component character only. Similar results were also noted by Johnson et al. (1955) in Soybeans and various others in different crops. In the case of seed yield, the discriminant function did not show much advantage over the straight selection.

On the contrary, the functions involving forage yield showed some superiority over the straight selection. Such results were noted by Robinson et al. (1951) in corn and Miller et al. (1958) in cotton.

Thus, although in the case of seed yield none of the selection indices considered gave a higher efficiency than that obtained from direct selection for seed yield alone, the use of the discriminant function seemed to have some advantage over straight selection in case of fodder yield. The selection index based on growth in spring, growth in fall, frost resistance, plant vigor and forage yield, showed an increased efficiency (G.A. = 3.763) over the other combinations, which indicates a relative efficiency of selection about 294.4% over the forage yield and first cut.

Though all these characters and the combinations studied in tetraploids were not studied in hexaploids, in general, the various combinations of selection indices considered seem to follow the findings for the tetraploids mentioned earlier.

SUMMARY AND CONCLUSION

Two sets of diallel crosses from the selected lines were produced to investigate the seed yield and vegetative production ability of various combinations and to study the genetic behavior of different quantitative characters associated with the main effects. The one set included seven tetraploid lines with their crosses and reciprocals; whereas the other set had five hexaploid lines and their one way crosses.

They were grown in a randomized block design with eight replications. Four replications were harvested for forage and the other four were used for seed yield test. The variety Grimm was used as a check and male sterile line 20DRC served the purpose of checking the percentage of cross pollination under the growing conditions at Edmonton, Alberta.

Data were obtained on fifteen quantitative characters in tetraploids and on nine of them in hexaploids during the two growing seasons. Further selection was made directly for the main characters, viz., seed yield, forage yield and dry matter yield per plant. The results of the present study may be summarized as follows:

1. The percentage of cross pollination was checked

in the field (University of Alberta Farm Parkland) by using male sterile line 20 DRC which was found to be 1.22%. Self fertility in the tetraploid and hexaploid lines under study was approximately 30% to 40%.

2. In general, heterosis expressed in percent of higher parent, was observed for seed yield, forage yield and dry matter yield in almost all the crosses of tetraploids; this was also true for hexaploids, except for cross 2 x 3 with respect to seed and forage yields, and cross 3 x 4 with respect to dry matter per plant which showed no dominance.

3. The crosses involving the tetraploid lines were found to be highly superior to the variety Grimm for seed, forage yield and dry matter yield. Though the seed yield of all crosses but 2 x 3 was higher than that of Grimm in hexaploids, the forage yield and dry matter content were found to be quite low.

4. The hybrids in general showed heterosis in tetraploids and also in hexaploids for seed yield, forage yield and dry matter per plant. In both groups the extent of heterosis was found to be greater for seed yield than forage and dry matter yields. Values as high as 577.35% and 526.48% over high parent were noted in tetraploids and hexaploids respectively for seed yield.

5. The variances and effects of specific combining

ability were relatively higher for most of the characters than general combining ability in tetraploids, which is expected in selected lines. In hexaploids the effects and variances of general combining ability were higher than specific combining ability which could be due to inclusion of the newly produced hexaploid line in the crossing program. In general, reciprocal differences were non-existent.

6. In general, lines 242 and 201 of tetraploids and lines 5 and probably line 1 of hexaploids are the superior selections on the basis of their general combining ability estimates. Crosses 201 x 242, 5 x 242 and 34 x 63 of tetraploids, and 3 x 5 of hexaploid may be expected to do better in such combination for most of the desirable characters under study.

7. The transmissibility measured in the form of broad and narrow sense heritability was estimated for all the characters. In general, narrow sense values were noted to be quite low in tetraploids but quite high in hexaploids, indicating the prominence of dominance and epistatic interactions in the first and additive and fixable genetic effects in the second case. It could be expected as the tetraploids were all selected whereas hexaploids had a newly synthesized line, the parents of which were previously selected.

8. The relationship of the performance of selfed and crossed progenies of these lines was calculated for each character by using correlation coefficients. Significant correlation for forage and seed yield between the two progenies was noted for line 16 in tetraploids and line 5 in hexaploids. All the possible correlation combinations are presented.

9. High and positively significant simple, genetic and phenotypic correlation coefficients were observed between the following combinations: first and second cut; first cut and total forage; second cut and total forage; first cut, forage yield and frost resistance; plant vigor and first, second cuts and total forage yield; seed yield and seeds per pod; dry matter per plant and frost resistance; dry matter and leaf area, frost resistance, plant vigor and plant height; leaf area and leaf length; frost resistance and plant vigor; leaf length and plant vigor; and growth habit and plant height. Though the value of simple correlation between forage and seed yield was very low, the high values at genotypic and phenotypic levels indicate their positive association.

10. In general, genetic correlation coefficients were higher than simple and phenotypic correlations; they had the same sign and magnitude as the phenotypic correlation.

11. In general, partial correlations between various combinations followed the same trend as the simple correlations.

12. The selection indices comprising the direct components of seed yield did not show any appreciable improvement over the straight selection in both tetraploids and hexaploids. The forage yield in tetraploid could be improved by using growth in spring and fall, frost resistance and plant vigor along with total forage yield in the selection criteria.

It seems logical to conclude that, as the tetraploid material was already well selected, it has showed more prominence of specific combining ability. Though further selection with it is plausible if based on the quantitative characters discussed, the specific hybrids or synthetic combinations may lead to more advantageous results. The hexaploids were poor in their growth, so any conclusion made on the basis of this study about selection might not be practical.

The breeding system which allows one to utilize the non-additive genetic variance as well as the additive would appear to be more promising. The use of F_1 hybrids or first generation synthetics would be preferable if the mechanics of seed production could be solved, especially in our tetraploid material.

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APPENDIX

TABLE I

MEAN VALUES OF VARIOUS CHARACTERS FOR ALL THE GENOTYPES OF DIALLEL CROSSING SYSTEM IN TETRAPLOIDS

Table I-1 First cut (Growth in spring 1969) - (T_1) - kg.

♀ Parents	male parents 5	16	34	63	67	201	242
5	0.563	0.869	0.844	0.802	0.675	0.898	1.072
16	1.113	0.967	0.969	0.950	0.883	0.946	1.168
34	0.814	0.978	0.672	0.932	0.782	0.865	0.866
63	0.835	0,920	1.113	0.595	0.826	0.848	0.936
67	0.870	1.130	0.942	0.818	0.630	0.975	0.987
201	0.954	1.098	1.079	1.025	1.058	1.026	1.077
242	0.909	1.011	0.804	0.850	0.899	1.189	0.653

Table I-2 Second cut (Growth in fall 1969) - (T_2) - kg.

5	0.554	0.767	0.791	0.830	0.751	0.821	0.937
16	0.896	0.753	0.947	0.798	0.851	0.873	0.908
34	0.754	0.723	0.620	0.926	0.733	0.879	0.693
63	0.830	0.813	1.048	0.723	0.847	0.876	0.977
67	0.782	0.904	0.859	0.838	0.635	0.892	0.919
201	0.916	0.983	0.924	1.008	0.879	0.897	1.095
242	0.869	0.890	0.823	0.864	0.821	0.976	0.773

Table I-3 Total forage yield 1969 - (T_3) - kg.

♀	male parents						
Parents	5	16	34	63	67	201	242
5	1.117	1.636	1.636	1.632	1.426	1.714	2.009
16	2.010	1.720	1.917	1.754	1.734	1.819	2.076
34	1.568	1.702	1.290	1.857	1.515	1.745	1.609
63	1.665	1.734	2.161	1.367	1.673	1.722	1.912
67	1.653	2.035	1.801	1.656	1.265	1.867	1.911
201	1.871	2.082	2.004	2.007	1.937	1.923	2.172
242	1.778	1.901	1.677	1.715	1.720	2.615	1.427

Grimm = 1.412

Table I-4 Seed yield per plant 1969 - (T_4) - gms.

5	8.815	15.14	13.16	17.20	11.15	16.64	33.45
16	24.46	6.132	15.41	18.06	21.85	29.22	38.49
34	16.38	11.15	4.372	25.59	11.18	9.702	30.95
63	19.03	19.57	23.40	3.475	23.23	27.55	24.37
67	13.00	28.56	16.18	16.90	2.20	21.10	23.91
201	25.01	19.38	16.85	24.84	15.66	9.007	37.27
242	37.09	27.32	16.09	27.58	26.63	28.23	9.797

Grimm = 9.286

Table I-5 Seeds per pod - (T_5)

♀	male parents						
Parents	5	16	34	63	67	201	242
5	2.545	2.965	3.720	2.740	2.487	3.172	3.477
16	2.970	3.382	3.422	2.960	3.060	3.152	3.417
34	3.542	3.510	3.120	3.435	3.762	3.462	3.755
63	3.157	3.217	3.420	2.372	2.775	3.160	2.983
67	2.495	2.907	3.467	2.760	2.382	2.947	2.995
201	3.130	3.005	3.110	2.932	2.637	2.595	3.460
242	3.755	3.400	3.585	3.200	3.187	3.175	3.075

Table I-6 Dry matter per plant - (T_6) - kg.

5	0.315	0.409	0.402	0.339	0.371	0.385	0.403
16	0.431	0.333	0.424	0.310	0.427	0.423	0.431
34	0.409	0.329	0.338	0.400	0.407	0.353	0.477
63	0.379	0.364	0.338	0.237	0.363	0.346	0.344
67	0.434	0.420	0.457	0.390	0.287	0.410	0.393
201	0.436	0.361	0.416	0.381	0.414	0.385	0.427
242	0.439	0.370	0.391	0.356	0.392	0.401	0.347

Grimm = 0.377

Table I-7 <u>Forage yield (1968 - year of establishment) - (T_7) - kg.</u>

♀	m a l e p a r e n t s						
Parents	5	16	34	63	67	201	242
5	0.802	1.095	1.019	0.935	0.820	1.211	1.180
16	1.062	1.070	1.299	0.834	1.096	1.256	1.149
34	1.114	1.063	0.977	1.108	1.039	1.200	1.128
63	1.092	1.033	1.149	0.770	0.945	1.181	1.047
67	1.051	1.058	1.128	0.998	0.774	1.274	1.071
201	1.416	1.345	1.475	1.393	1.345	1.529	1.483
242	1.123	1.135	1.050	1.149	1.020	1.277	0.919

Table I-8 <u>Leaf Area (middle leaflet)</u> - (T_8)- cms.

5	2.347	2.322	2.376	2.409	2.488	2.615	2.317
16	2.345	2.026	2.142	2.051	2.536	2.245	2.340
34	2.338	2.187	2.242	2.389	2.279	2.390	2.456
63	2.269	2.326	2.411	2.162	2.584	2.452	2.330
67	2.745	2.664	2.525	2.663	2.614	2.742	2.643
201	2.671	2.408	2.701	2.791	2.644	2.784	2.665
242	2.461	2.429	2.335	2.290	2.602	2.448	2.400

Table I -9 Leaf length (Middle leaflet) - (T_9) - cms.

♀	male parents						
Parents	5	16	34	63	67	201	242
5	2.43	2.36	2.36	2.51	2.41	2.52	2.42
16	2.33	2.16	2.20	2.26	2.39	2.22	2.32
34	2.36	2.20	2.23	2.43	2.23	2.28	2.32
63	2.47	2.41	2.42	2.51	2.60	2.53	2.42
67	2.62	2.41	2.40	2.59	2.56	2.52	2.47
201	2.56	2.36	2.44	2.67	2.42	2.52	2.48
242	2.39	2.36	2.26	2.35	2.42	2.39	2.22

Table I-10 Frost resistance -(T_{10})

5	7.48	7.94	7.70	7.81	7.78	8.01	8.35
16	7.89	8.02	8.16	7.79	7.77	7.99	8.40
34	7.64	7.78	7.64	7.93	7.62	7.78	8.05
63	7.94	8.05	7.80	7.45	7.87	7.78	8.20
67	7.76	8.13	7.93	7.83	7.62	8.02	8.26
201	8.14	8.39	8.14	7.92	8.18	8.11	8.66
242	8.34	8.30	8.04	8.14	8.26	8.50	8.23

Table I-11 Plant vigor -(T_{11})

♀	male parents						
Parents	5	16	34	63	67	201	242
5	6.86	7.46	7.10	7.34	7.19	7.31	7.55
16	7.67	7.14	7.21	7.34	7.84	7.60	7.75
34	7.17	7.11	6.77	7.41	7,03	7,08	7.26
63	7.35	7.54	7.61	6.99	7.48	7.31	7.48
67	7.52	7.75	7.40	7.43	7.24	7.82	7.56
201	7.43	7.33	7.70	7.78	7.46	7.61	7.76
242	7.68	7.69	7.44	7.45	7.37	7.72	7.40

Table I-12 Growth habit -(T_{12})

5	7.18	7.00	6.87	7.28	6.82	6.81	6.83
16	6.97	6.73	6.73	6.73	6.71	6.58	6.67
34	6.86	6.80	6.71	6.72	6.68	6.68	6.74
63	7.11	6.85	6.78	6.73	6.72	6.63	6.70
67	6.76	6.68	6.58	6.74	6.52	6.51	6.58
201	6.68	6.44	6.50	6.65	6.55	6.36	6.55
242	6.84	6.70	6.65	6.73	6.58	6.62	6.69

Table I-13 <u>Height at maturity</u> - (T_{13}) - cms.

♀	male parents						
Parents	5	16	34	63	67	201	242
5	109.67	111.70	120.97	107.17	114.00	111.22	107.55
16	110.87	96.77	105.17	97.6	108.37	102.22	100.27
34	121.52	109.55	111.77	109.6	116.57	113.77	110.72
63	114.07	98.17	107.22	90.47	103.62	94.37	96.50
67	128.52	107.52	118.97	107.72	107.35	106.92	106.97
201	110.32	95.10	102.37	98.35	105.85	98.82	96.20
242	106.82	98.85	110.47	94.70	105.10	95.90	98.22

Table I-14 Per cent of pod set in crosses -(T_{14})

♀	male parents						
Parents	5	16	34	63	67	201	242
5	.....	48.38	29.39	35.71	22.50	31.74	30.85
16	35.74	.....	38.30	49.15	25.86	35.21	31.35
34	30.32	15.11	.....	22.62	15.80	32.00	33.11
63	22.59	58.25	32.00	.....	19.20	32.48	66.32
67	22.59	41.58	26.92	27.77	.....	32.04	26.19
201	36.32	60.00	40.46	41.71	45.45	.....	54.42
242	22.50	48.67	35.89	44.00	55.05	55.10	.....

Table I-15 Number of seeds per pod set during crossing - (T_{15})

5	....	4.00	4.30	4.06	3.21	2.44	6.57
16	3.95	....	2.73	2.76	4.54	4.70	3.15
34	3.65	4.11	....	2.60	2.88	1.72	2.10
63	3.00	4.45	3.75	....	2.69	3.51	3.87
67	3.00	3.43	2.69	3.08	....	3.27	3.01
201	4.26	5.22	4.13	4.48	4.56	.....	3.68
242	4.44	3.72	4.13	3.86	4.07	3.98	....

TABLE II

MEAN VALUES OF VARIOUS CHARACTERS FOR THE GENOTYPES OF DIALLEL CROSSING SYSTEM IN HEXAPLOIDS

Genotypes	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
1⊕	0.405	0.447	0.883	2.798	1.44	0.137	93.6	-	2.30
1x2	0.392	0.510	0.902	3.620	1.60	0.167	94.5	38.79	3.81
1x3	0.344	0.550	0.894	6.266	1.58	0.149	93.4	38.13	3.64
1x4	0.373	0.625	0.998	9.625	1.89	0.177	96.1	46.09	4.32
1x5	0.517	0.822	1.339	14.731	2.53	0.211	93.3	43.67	3.78
2⊕	0.339	0.462	0.801	1.836	1.49	0.154	95.8	-	2.02
2x3	0.230	0.282	0.512	1.926	1.36	0.317	77.2	24.79	2.66
2x4	0.469	0.612	1.082	6.747	1.73	0.203	99.4	23.18	2.94
2x5	0.466	0.765	1.231	10.252	2.24	0.226	98.3	43.56	3.26
3⊕	0.317	0.485	0.800	3.249	1.31	0.171	92.5	-	2.05
3x4	0.357	0.522	0.880	5.904	1.85	0.142	87.7	32.88	3.91
3x5	0.562	0.795	1.357	16.612	1.97	0.270	97.1	46.15	4.33
4⊕	0.278	0.440	0.727	4.994	1.58	0.137	90.8	-	1.85
4x5	0.553	0.582	1.145	7.367	2.02	0.202	94.4	44.82	2.97
5⊕	0.363	0.602	0.988	2.604	1.76	0.207	88.8	-	1.80

X_1 = First cut (kg), X_2= Second cut (kg), X_3 = Total forage yield 1969 (kg), X_4 = Seed yield per plant (gm), X_5 = Seeds per pod, X_6 = Dry matter content per plant (kg), X_7 = Plant height at maturity (cms.), X_8 = Percentage of pod set during crossing, X_9 = number of seeds set per pod during crossing.